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16. ABSTRACT

Probable changes in the mix of materials usnd to manufacture automobiles were examined to determine if economic or technical problems in recycling could arise such that the "abandoned automobile problem" would be resurrected. Future trends in materials composition of the automobile were quantified, and possible constraints related to material characteristics, availability, and price were examined. The automobile resource recovery industry was studied in terms of economic incentives for recycling and technical obstacles to recycling of deregistered automobiles. A macro-model of the economy, the EPA sponsored SEAS model, was used to study overall economic and environmental effects and to bring to light any secondary effects that might be important.

This volume contains appendices covering the following subjects:

1) Future Scrap Requirements and Prospects for Automotive Recycling.
2) Demand, Availability, and Price of Steel and Substitute Materials for Automobile Manufacture.

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APPENDIX F

FUTURE SCRAP REQUIREMENTS AND PROSPECTS FOR AUTOMOTIVE RECYCLING

by W. L. Henn

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F.1 INTRODUCTION

The recovery of metallic constituents has historically been emphasized in automobile reclamation efforts. Other materials such as textiles, plastics, and glass are usually treated as unwanted residuals and, as such, are burned or disposed of in the solid waste stream. Metals recovery efforts by the scrap processing industry, in turn, are overwhelmingly directed toward the segregation, processing, and sale of the ferrous portion. Steel comprises 61.2 percent and cast iron 10.2 percent of the Renner 1975 composite car.[1] The ferrous proportion is undoubtedly higher in the representative midsixties car that is presently the typical automotive candidate for retirement and processing. Other recoverable metallic constituents such as zinc, copper, and aluminum are segregated where feasible--often at the auto wrecking rather than scrap processing stage--and sold to the respective secondary or primary producers. In terms of quantity as well as economic viability,[2] the predominant product of automobile materials recovery at the scrap processing level is ferrous scrap. An examination of the structure and dynamics of the market for this product is important, not only to allow for an assessment of the future prospects for reutilization of the resources which will be present in obsolete vehicles, but also to provide a context within which to view that segment of the industry which will undertake this reclamation in light of changing composition of these resources.

This evaluation will proceed in four parts: an examination of the types of ferrous scrap and the patterns of their usage; an assessment of future domestic and foreign requirements for scrap on the basis of the needs of iron and steel industries at home and abroad; a discernment of the trends apparent in the utilization of automobile derived scrap; and an estimate of the availability of ferrous material from deregistered automobiles.

Automobiles are but one source for a particular category of ferrous scrap. Accordingly, an initial discussion of the types of ferrous

scrap is necessary. Qualitatively, characteristics pertinent to desirability and utilization in each category will be outlined. Quantitatively, the extent to which scrap in each category has been consumed in the recent past will be examined.

Second, the iron and steel industries will be examined to provide a basis for an assessment of future scrap requirements. The relationship between production processes and scrap requirements will be probed. Based on an anticipated future mix of these processes as well as expected levels of iron and steel production, projections of future domestic scrap requirements through 1985 will be presented. Export requirements for scrap, based on anticipated global steel production levels, will then be estimated over the same period.

Third, the grades of scrap derived in part from processed automobiles, shredded and number two baled, will be examined. Past utilization trends will be extrapolated into the future; relationships between the outputs of the respective grades and autos processed will then be utilized to arrive at an estimate of past and future annual processing rates.

Finally, estimates of past, present, and future car deregistration rates will be used to arrive at annual figures for new ferrous scrap availability from this source in the case of constant car composition and in the case of changing automobile composition.

This four part examination facilitates the formulation of informed judgments on three important questions.

What annual and cumulative proportion of cars will be recycled? The difference between the scrap made available from annually deregistered cars and a certain portion of the scrap which was and will be consumed annually from the two relevant grades can be used to venture an answer to this question.

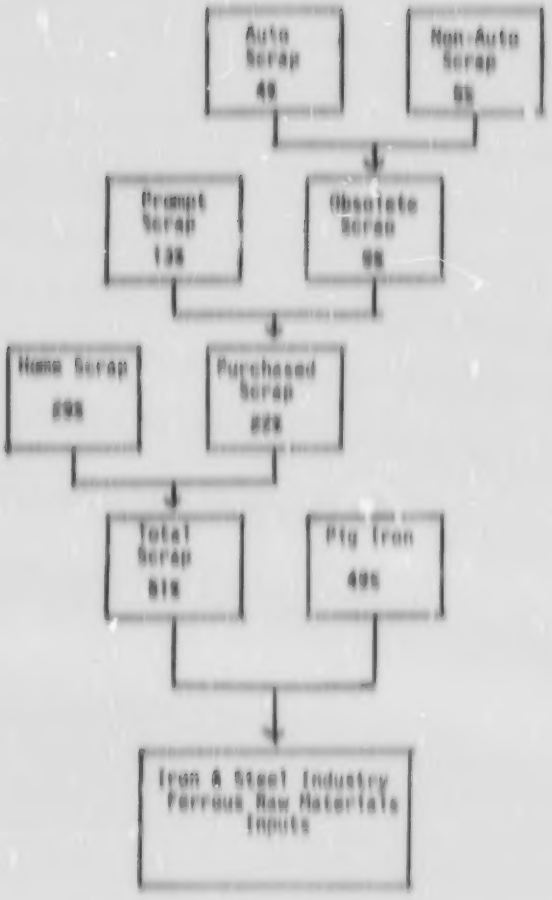
What will be the future posture of the shredder and baler in the

processing industry? The tradeoff occurring in the past and expected in the future can be quantified on the basis of the respective normalized consumption trends. Anticipating some results for a moment, calculating the size of scrap requirements in excess of availability from deregistrations after depletion of the backlog permits a further assessment. Specifically, an estimate of the percentage that scrapped automobiles will be of the total ferrous input to the shredder and baler segments of the scrap processing industry can be made on the basis of the aforementioned computation.

What effect will the changing composition of new automobiles have on their recycling rate and the processing industry? The foregoing assessments of automobile recycling and processing industry posture may be reexamined in light of the changing composition of future automobiles. The first set of estimates in these two areas assume the deregistration of a constant composition car from which approximately 1700 lbs. per scrapped vehicle is recovered via the shredding or baling route. By appropriately adjusting this figure of 1700 lbs. in line with Renner's projection of future ferrous content, a second assessment of recycling prospects and industry posture can be made.

F.2 Types of Ferrous Scrap

Ferrous scrap is typically categorized in accordance with its source.[3] Figure F1 shows the flow of scrap to the iron and steel industries. Scrap generated by steel mills and iron and steel foundries in the production and finishing process and recycled without passing through the facilities of the scrap industry is designated as home scrap. Due to reporting peculiarities, the small quantity of obsolete scrap generated and utilized by these production units without external processing is included with the recirculating scrap in an accounting of home scrap utilization. Metal-working firms generate scrap while fabricating industrial or consumer products. This is routed back to production units through fairly stable channels



1973 figures and estimates

Figure 1. Sources of Ferrous Inputs to Domestic Iron & Steel Industry

which sometimes involve processing or brokerage by instrumentalities of the scrap industry. Finished products disposed of by final users which are collected, processed, and marketed by elements of the scrap industry are classified as obsolete scrap. The latter two sources of scrap are external to the steel or iron production unit and, for that reason, are often grouped together as purchased scrap.

Home scrap generation figures are presented in Table F1. These numbers are linked not only to the quantity of production, but also the nature of the process employed and product specifications. Iron and steel foundries produce from 40 to 60 percent by weight home scrap per unit of melted iron or steel.[4] Calculations for the period from 1965 to 1969 show that steel shipments as a percentage of raw steel production were 68 percent, implicitly suggesting a ratio of home scrap to raw steel near 32 percent for the industry as a whole.[5] Similar calculations for the period 1970-1972 suggest a scrap generation ratio of 30 percent, perhaps indicating a change in the trend of rising scrap ratios in the steel industry which has been observed by Battelle in the period 1950-69.[6] Home scrap segregation and preparation is minimal; the quality is good, known, and compatible with requirements. Utilization of available home scrap must be considered to be nearly complete.

While the quantity of purchased scrap is known accurately for a given year, the proportions that obsolete and prompt scrap constitute within that total can be only estimated. A procedure adopted and utilized by Battelle[7] in 1972 is summarized in Tables F2, F3, F4 for the period 1960-1970 and updated for the remaining years. Roughly 60 percent of the purchased total is attributable to prompt scrap and the remainder to obsolete. These proportions are open to dispute; they are reversed in a study made by the Business and Defense Services Administration in 1966.[8] Placing more trust in the more recent study has been suggested elsewhere,[9] and the method developed therein will be adhered to in this assessment.

TABLE F1

[illegible] SCRAP GENERATED BY

[illegible] AND TYPES OF MANUFACTURER, 1960-1973

(thousand short tons)

Year	Steel Industry	Iron Foundries[a]	Steel Foundries	Total
1960	N.A.	N.A.	N.A.	39,632
1961	N.A.	N.A.	N.A.	38,475
1962	N.A.	N.A.	N.A.	40,644
1963	37,838	5,884	1,353	44,656
1964	44,774	5,988	1,496	52,260
1965	46,970	6,660	1,585	55,213
1966	46,920	6,930	1,613	55,463
1967	44,315	6,532	1,460	52,312
1968	46,639	6,740	1,166	53,545
1969	49,257	6,814	1,216	56,287
1970	46,394	5,149	1,032	52,575
1971	42,008	6,691	870	49,569
1972	44,411	5,970	793	51,184
1973	50,409	6,587	826	57,001

[a] Includes miscellaneous products.

Source: Bureau of Mines Minerals Yearbook 1960-1971, "Iron and Steel Scrap" Preprint, 1973.

The volume of prompt scrap generated is obviously tied to the level of activity in the metal working industries, which is assumed to be evidenced by their consumption of steel mill shipments. The nature of the fabrication process and the raw steel grade involved also influence prompt scrap generation. The generation ratios indicated in the tables were arrived at by Battelle on the basis of previous studies as well as specific inquiries made on the subject for the 1972 report.

Once generated, this material is either collected and shipped directly to a production unit, or it is subjected to some combination of cleaning, segregation, and packaging that can involve the scrap processing industry prior to delivery. The quality of prompt scrap is generally good and known, its source is established, and its volume is dependable. Again, these factors are incorporated into the estimates through the assumption that all prompt scrap available is consumed.

While some obsolescent materials of good and known composition in accessible locations such as structural components, ships, and machinery are readily recycled, a large portion of obsolete goods with significant ferrous content lack these attributes in varying degrees. Thus, this scrap source is the least desirable; its utilization tends to be dictated by demand exceeding the availability of home and prompt scrap.

Lacking published information on the geographic sources of these materials, the best indicator is the relative distribution of the population with adjustments for relevant economic activities and social developments.[10] Industrial and urban centers generate a proportionately larger amount of scrap; certain rural based economies are significant generators since they attract appliances and autos for secondary use in addition to discarding equipment from productive economic activities. Rural obsolescent scrap presents formidable recovery problems: sparseness of processing facilities and resulting high transportation costs make recycling a marginal enterprise.

The National Environmental Research Center estimates that 66.7 million tons of obsolete scrap became available in 1970. The annual availability

[illegible]

[illegible]

[illegible]

[illegible]

Year	[illegible]	[illegible][1]	[illegible]	[illegible][2]	[illegible]
[illegible]	71,551	14,306	13,175	499	14,805
[illegible]	67,208	13,468	12,702	535	14,005
[illegible]	72,625	14,528	13,684	497	15,179
[illegible]	78,777	15,755	15,475	754	16,508
[illegible]	87,543	17,508	17,455	555	18,063
[illegible]	105,553	21,111	18,779	556	21,667
[illegible]	95,024	19,005	16,867	502	19,769
[illegible]	91,667	18,733	17,139	656	19,395
[illegible]	97,645	21,535	17,778	886	22,421
[illegible]	102,657	20,531	16,963	542	21,473
[illegible]	97,335	19,472	16,307	835	20,307
[illegible]	102,356	20,471	16,388	815	21,286
1970	106,477	21,343	16,923	887	22,196
1971	122,005	24,401	21,396	1005	25,405

[illegible]

[1] [illegible]

[2] [illegible]

[illegible]

Source: [illegible], [illegible], [illegible],

TABLE F3

OBSOLESCENT SCRAP-ESTIMATE OF RECYCLING 1960-1973

(thousand short tons)

Year	Total Domestic Receipts of Purchased Scrap	Prompt Industrial Scrap	Estimated Obsolescent Scrap	Obsolescent % of Total Purchased Scrap
1960	25,095	14,995	11,100	44.2
1961	25,105	14,096	11,009	43.8
1962	25,269	15,219	10,050	39.8
1963	29,432	16,509	12,923	43.9
1964	31,831	18,444	13,387	42.1
1965	35,009	21,047	14,757	41.8
1966	36,671	20,748	15,923	43.4
1967	32,454	19,589	13,065	40.1
1968	33,587	22,415	11,172	33.3
1969	36,929	21,478	15,451	41.8
1970	34,148	20,238	13,910	40.7
1971	33,983	21,286	12,697	37.4
1972*	41,870	22,184	19,686	46.9
1973*	44,711	25,415	19,296	43.1

*Prompt total based on Bureau of Mines estimate for Production, Imports and Exports for 1973 in Commodity Data Summary 1975, p. 88.

Source: 1960-1970: Battelle estimate based on information from Institute of Scrap Iron and Steel, 1970 Yearbook. 1971-1973: purchased scrap from Bureau of Mines Minerals Yearbook 1971-73, and "Iron and Steel Scrap" Preprint, 1975 by computing receipts-shipments in total table.

is projected to fall to 49.6 million tons in 1975, and then rise to 66.7 million tons in 1980, and 91.4 million tons in 1985. The recycling rate, estimated to be about 45 percent in 1970, is expected to fall in the range of 25-40 percent by weight in 1985.[11] Battelle estimates that newly available obsolete scrap in 1970 totalled 56.7 million tons with a reservoir of 750 million tons having been accumulated prior to that year.[12]

Automobiles are the largest single source of utilized post-consumer scrap, comprising 30 to 40 percent of the total processed annually.[13] This represented less than a fifth of the purchased and less than a tenth of all scrap consumed in 1973. Recycling rates for automobiles have recently approximated 85 percent, showing their relative desirability with respect to obsolete ferrous scrap in general.

The various sources of scrap are not only differentially interchangeable among themselves, but they also compete with virgin ore as a ferrous input to the iron and steel industries.

The composite figures for scrap utilization in table F4 show that while total scrap consumption rose 66 percent from 66.5 to 103.6 million tons in the period 1960-73, home increased 46 percent from 39.6 to 57.8 million tons, and purchased gained 71 percent in moving from 26.1 million to 44.7 million tons provided annually. Within the purchased category, prompt scrap utilization rose 70 percent in going from 15.0 to 25.4 million tons, while obsolescent utilization increased 74 percent from 11.1 to 19.3 million tons annually.

These figures are analyzed in terms of their respective parts of the total ferrous input to the iron and steel industries in the succeeding compilation in Table F5 and Figure F2. Total scrap shows a very gradual rise from just below to a bit above half the total in the 14 year period. The trend, noted elsewhere,[14] of increasing relative home scrap usage in the mid-sixties accompanied by a decline in the relative purchased portion in that decade, is apparently shifting in the early part of this decade. The proportion of prompt scrap shows a steady slight upward movement in the sixties, while the obsolete part is more erratic and falling in the latter part of the decade. However, the use of postconsumer scrap relative to other ferrous

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1960	66,469	65,177	39,655	34,985	14,395	11,708	1.1
1961	64,307	63,788	39,475	35,305	14,296	11,359	0.9
1962	65,760	65,329	40,248	35,394	15,219	10,895	0.8
1963	74,421	74,387	46,655	39,402	16,329	12,923	0.7
1964	84,826	84,593	52,352	41,631	18,488	13,387	0.6
1965	90,359	91,877	56,273	35,884	27,067	14,777	0.7
1966	91,593	92,734	55,483	34,671	29,748	15,503	0.8
1967	85,307	84,966	52,372	32,654	19,589	12,865	0.5
1968	87,283	87,732	53,546	30,587	22,415	11,172	0.1
1969	94,876	93,276	56,283	36,329	27,478	15,457	1.7
1970	85,559	86,723	52,575	34,748	28,258	13,970	1.4
1971	82,367	83,752	48,749	33,983	27,286	12,697	0.7
1972	91,371	92,854	51,364	41,670	27,284	13,486	0.6
1973	103,586	102,512	57,881	44,711	25,415	15,256	1.0

Note: [illegible] = Purchased - Project

Source: 1960-1970 Detroit Edison archives, [illegible] 1970 Yearbook data. 1971-1973: project and absolute difference based on Bureau of Mines Domestic Data Submittals 1971 data, and other from Bureau of Mines Minerals Yearbook, 1971-2, and "Coal and Steam Scrap" Projection for 1973.

TABLE 15

IRON AND STEEL SCRAP CONSUMPTION AS A % OF ACCEPT
OF TOTAL METALLICS TO IRON AND STEEL INDUSTRIES

Year	Total Scrap[a]	New Scrap[b]	Purchased Scrap[b] (prompt & obsolete)	Prompt Scrap[b]	Obsolete Scrap[b]
1960	48.2	28.7	19.5	11.2	8.3
1961	46.7	28.3	18.7	11.0	8.7
1962	46.8	28.7	18.1	11.5	7.6
1963	50.7	28.6	22.1	11.3	9.8
1964	47.5	28.7	18.8	10.8	8.0
1965	50.4	28.6	19.8	11.6	8.2
1966	48.9	28.0	19.9	11.2	8.7
1967	46.4	28.4	18.0	11.4	7.6
1968	46.2	28.6	18.6	12.4	6.2
1969	50.0	28.2	19.8	11.5	8.3
1970	46.5	28.4	18.1	11.3	7.8
1971	50.4	28.6	20.6	12.9	7.7
1972	51.2	28.2	23.0	12.2	10.8
1973	50.9	28.7	22.2	12.6	9.6

[a] Source: Bureau of Mines, Mineral Yearbook 1960-72, "Iron and Steel Scrap" Preprints 1973.

[b] From Table 4, "Availability and Consumption of Ferrous Scrap 1960-73" with sources as noted. Since availability approximate each other year by year, relative scrap source percentages are assumed to apply to total consumption figure in column a.

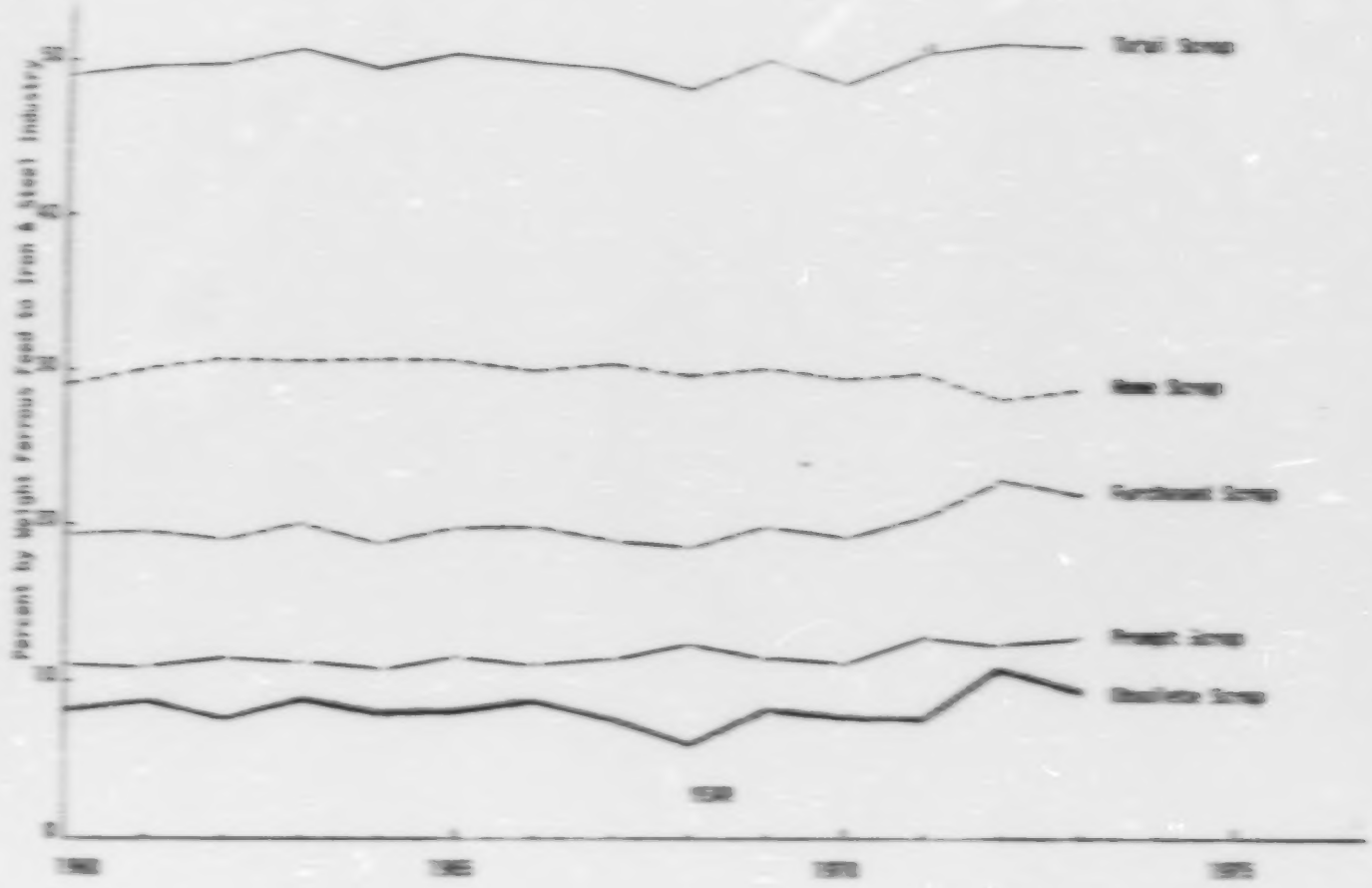


Figure F2. Scrap Utilization Relative to Total Ferrous Input to Domestic Iron and Steel Industry

sources rises in the early part of the seventies. The relative undesirability of obsolete scrap utilization seems to be indicated by this behavior: an erratic, disproportionate rising and falling to furnish the difference between a relatively constant rate of generation and utilization of home and prompt scrap and annual scrap requirements.

E.3 Future Scrap Requirements

These undercurrents of scrap type tradeoff exist in the much greater milieu of overall scrap requirements dictated largely by the consuming processes in the iron and steel industries. The steel industry presently utilizes three major furnace types, each with a different scrap requirement; the iron castings industry is dominated by a fourth furnace type with yet another set of ferrous input characteristics. Changes in the respective proportions of total production obviously affect scrap utilization.

Steel mills account for about 80 percent of ferrous scrap consumption; foundries utilize 19 percent.

The declining importance of the open-hearth process accompanied by the increased utilization of the basic oxygen and electric furnaces mark the major trends in the steelmaking industry. Virtually all ingot production utilized the open-hearth process in 1950; this method accounted for slightly more than a third of production by the beginning of the present decade. Simultaneously, raw steel produced by the basic oxygen furnace increased from nothing to 63.3 million tons and half the total output in the same 20 year period. Electric furnace production also grew in this time frame until it comprised one-fifth the total production in 1970. A summary of past trends and an estimate of future posture by Battelle is presented in Table F6.

The charge to the respective steelmaking furnaces is determined by a complex set of factors, the most prominent of which are technological considerations involving heat balance, charging procedures, and product requirements and economic considerations involving availability and cost of

| | | |

substitute materials or processes.[15] The interplay of these influences yielded steelmaking scrap charges in 1973 as follows:

Process	Pig Iron	Scrap
Basic Oxygen	71 percent	29 percent
Open Hearth	56 percent	44 percent
Electric	3 percent	97 percent

Source: U.S. Bureau of Mines, Minerals Yearbook, "Iron and Steel Scrap," (Preprint 1973).

These fractions have remained fairly constant since the midsixties: the scrap charge to the open hearth process has increased slightly from between 41 and 42 percent, and the scrap portion of the electric furnace charge has diminished from 99 percent to its present proportion.

Raw material consumption data indicates that the cupola and electric furnaces are the principal production units in the iron and steel castings industries, respectively:

1973 Foundry Industry Consumption of Scrap and Pig Iron
(thousand short tons)

	Iron Foundries		Steel Foundries	
	Scrap	Pig Iron	Scrap	Pig Iron
Open Hearth	---	---	138	10
Electric	4,242	434	2,496	41
Cupola	13,245	1,967	286	8
Other	506	228	29	5
TOTAL	18,173	2,619	2,949	64

Source: U.S. Bureau of Mines, Minerals Yearbook, "Iron and Steel Scrap". (Preprint 1973)

A survey conducted in the late sixties indicated that 90 percent of all gray iron was produced in the cupola furnace with more significant contributions from electric furnaces being felt in the production of

ductile and malleable iron. Additionally, it found that 70 percent of all steel casting was carried out in electric furnaces, the remainder attributable to open hearth processes.[16]

Scrap charges to cupola furnaces have increased steadily from 72 percent in 1960 to the 87 percent indicated by the recent figures previously presented. Scrap charges to electric furnaces, discussed previously, exceed 95 percent in the castings industries. Composite scrap charge to the steel castings industry is about 98 percent; the charge to the iron casting industry exceeds 87 percent. There has been some replacement of cupola with electric capacity that is expected to continue at a slow rate.[17]

The foregoing considerations of different scrap charge to different furnace type and varying furnace type proportions of total production were combined with anticipated future production levels by Battelle to obtain estimates of future scrap requirements. These are presented in Table F7. Assuming that the enlargement of purchased scrap demand due to increased use of continuous casting techniques will be offset somewhat by increased use of prereduced ores or scrap substitutes, these numbers indicate that while the output of the iron and steel industries will increase by 49 percent in the 15 year period, total scrap requirements will grow by 58 percent. Additionally, the proportion of purchased scrap increases over the same time span.

A recent discussion of 1973 United Nations assessments[18] of future steel production on a global basis suggests that U.S. steel production will total 149 thousand tons in 1975, 170 thousand tons in 1980, and 180 thousand tons in 1985. Only the final estimate is significantly lower than the Battelle figure. These projections by UNIDO indicate worldwide basic oxygen: open-hearth: electric furnace ratios of 62.0: 17.1: 20.0 in 1980, and 65.0: 6.5: 30.0 in 1985. Since examination of the United Nations data on this proportion for the benchmark years of 1960, 1965, and 1970 shows that the global proportions parallel the previously presented (see Table F6) U.S. domestic distribution within

| | | |

a few percentage points (there is a slightly larger discrepancy of about 8% for the basic oxygen proportion in 1970), the general agreement of the global projections with the domestic projections by Battelle (see Table F6) serves as a rough verification of the latter furnace proportion estimates. Thus, this UNIDO study suggests that only the general level of activity assumed by Battelle in estimating future scrap requirements need be adjusted. This uncertainty is introduced in Figure F3 where a lower estimate for future scrap requirements is plotted assuming domestic and purchased scrap requirements are lowered in proportion with the lower UNIDO estimate for U.S. domestic steel production.

The export market is the second great consumer of domestic scrap. In 1973, over 11.4 million tons were exported. This is equivalent to 10 percent of domestic consumption or 25 percent of domestic purchases of iron and steel scrap. Moreover, it is generally agreed that obsolescent scrap constitutes a much greater proportion of exported than domestic purchased scrap.

Firm estimates of future exports would require a country by country detailed study in its own right. Since exports are a minor consumer of scrap relative to the domestic iron and steel industry, an order of magnitude estimate will suffice. Table F8 suggests a method for accomplishing this rough approximation by analyzing the historic relationship between world raw steel production excluding the United States and U.S. exports which serve as an input to that production. The consistently higher ratio in the early sixties can probably be ignored for a number of reasons, prominant among which is the fact that the world mix of production processes was then dominated by the open-hearth furnace (worldwide as well as domestically). This composite situation undoubtedly had a different relationship between scrap inputs and steel production than current or anticipated situations. Though the ratio displays considerable variability in the 5 most recent years, the magnitudes are the same: they range between .013 and .021. The data in Table F9 indicates that the requirements for scrap in relation to world production will not change

[illegible]

[illegible]

	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Source: [illegible]

TABLE F9

WORLDWIDE STEEL PRODUCTION & SCRAP REQUIREMENT
(million short tons)

	Raw Steel Production	Estimated Total Scrap Required	Ratio- Scrap Production
1969	636	364	.57
1975	810	413	.51
1980	1009	540	.54
1985	1130	606	.54

Source: "On-Site Processing of Iron Ore in Developing Countries Through the Stage of Prereduced Agglomeration"; UNIDO Third Interregional Symposium on the Iron and Steel Industry; Document ID/WG. 146/5A Brasilia; October 1973. In J.R. Miller "Iron and Steelmaking Metallics Demand and Supply 1975-1985", June 5, 1974.

TABLE F10

STEEL PRODUCTION GROWTH BY MAJOR IMPORTERS OF
U.S.IRON AND STEEL SCRAP
(million short tons)

U.S. Scrap Importer	% U.S. Exports of Ferrous Scrap 1973	Raw Steel 1973	Raw Steel[c] Production 1973	Raw Steel[c] Production 1980	Raw Steel[c] Production 1985	% Growth 1973-85
Japan	41	131.1	141.0	176.4	189.6	45
Remainder of North America	16	80.0	82.1	96.7	93.1	66
Spain	10	11.8	12.1	16.5	20.0	66
3 Major Importers		162.9			244.7	50
World Excluding U.S.	100	815	882	836	950	54

[a] From U.S. Bureau of Mines Minerals Yearbook "Iron and Steel Scrap" Preprint 1973.

[b] From U.S. Bureau of Mines Minerals Yearbook "Iron and Steel Scrap" Preprint 1973.

[c] J.R. Miller "Iron and Steelmaking Metallics Demand and Supply: 1975-1985" prepared for 77th National Meeting American Institute of Chemical Engineers, Pittsburgh; June 5, 1974. p.12.

markedly, though perhaps showing a slight overall decline. The projected growth in steel production by the major importers of U.S. ferrous scrap, examined in Table F10, is expected to be very close to the world rate through 1985. Assuming that the relative scarcity of ferrous resources that has caused Japan and Spain to be major buyers and the additional geographical considerations leading Mexico and Canada to be large consumers of scrap from the United States will continue to be important factors in the next decade, exports of scrap from the United States can be anticipated to roughly grow with world production of raw steel. The precision of this estimate is indicated by the large uncertainty band in Table F8 for the projection years in question. The anticipated export requirements are displayed in Figure F3.

One further caveat must be introduced: the possibility of export controls in the future. An annual quota of 8.4 million tons, imposed in 1974 amidst the furious demand for scrap, has been lifted in 1975. Reinstitution of restrictions would obviously dictate the level of ferrous scrap exports.[19]

F.4 Scrap Derived From Automobiles

A study completed in 1973 for the National Environmental Research Center by Booz-Allen Research, Inc. developed and utilized a scheme for estimating the number of obsolete automobiles processed into scrap in a given year on the basis of scrap recycled.[20]

Automobiles are processed into scrap primarily by baling or shredding; a few are sheared into slabs. By obtaining estimates for the respective fractions of output attributable to processed automobiles in these three processes, published data on number two bundle output--the grade of scrap produced when an auto is baled--and estimates for the output of the other two processes were utilized to arrive at a figure for the number of cars processed annually from 1958-70. Since 1970, data has been published by the Bureau of Mines for not only the output of number two

Figure F3. Total Scrap Requirements for the United States

bundles, but also for that of shredded scrap. Assuming that the proportions of the various scrap grades attributable to scrapped automobiles have not changed appreciably from those arrived at for the 1973 report, this recent data can be utilized to update the status of auto recycling to 1974.

Furthermore, by examining the trends in shredded scrap and number two bundle receipts as a part of both domestic purchased and exported scrap, previous endeavors to quantify future scrap requirements in these two areas can be drawn upon to estimate future annual automobile recycling rates. This undertaking will proceed initially with the assumption that the estimates of the automobile portions of number two bundles and shredded scrap developed in the Booz-Allen study will remain the same through 1985. Specifically, this report estimated that material of automotive origin accounted for 60-75 percent of the ferrous output of balers and 70-82.5 percent of the same for shredders. It will be further assumed that when the supply of deregistered autos is exhausted (including inventory from previous years), short falls in automotive availability will be made up from other obsolete sources to meet predicted demand. With little fear of error, it also will be assumed that the overall production of automobile slab will remain small and, with some fear of a small error, it also will be assumed that it remains constant.

The trend in net purchases of number two bundles and shredded scrap as a portion of total net domestic purchases is examined in Table F11 and Fig. F4. Note the steady, marked rise in the proportion of shredded scrap from 2.2 percent in 1969 to 7.9 percent in the first quarter of 1975. The fraction of number two bundles exhibits a clear, although somewhat erratic, decline in the same period, dropping from 10.2 to 6.4 percent of net domestic purchases in that time span.

The plot of the actual data is projected over the next decade with a linear least squares fit regression line. The actual as well as projected percentages attempt to quantify the tradeoff between baler and shredder processing which has been noted and forecast elsewhere[21,22]-- a tradeoff which will be examined more closely in a more particularized view of the ferrous scrap processing industry developed in a later appendix. Moreover, the graph indicates that shredded scrap output

TABLE F11

PROPORTIONS OF #2 AND ALL OTHER BUNDLES AND SHREDDED SCRAP OF ALL DOMESTIC PURCHASED SCRAP
(thousand short tons)

Year	Net Total Purchased	Net Purchases #2 and All Other Bundles		Net Purchases Shredded Scrap		#2 & Shredded % of Total
			%		%	
1969	36,929	1,699	10.2	799	2.2	12.4
1970	37,148	3,469	9.3	878	2.4	11.7
1971	35,983	2,617	7.7	1674	4.9	12.6
1972	41,670	3,133	7.5	2062	4.9	12.4
1973	44,711	3,609	8.1	2430	5.4	13.5
1974[a]	47,960	4,048	8.4	3182	6.6	15.0
1975[a] (1st Quarter)	10,701	884	8.4	848	7.9	14.3

[a]Preliminary data.

Source: 1969-73: U.S. Bureau of Mines, Minerals Yearbook 1969-73, and "Iron and Steel Scrap" Preprints for 1973. 1974-75: U.S. Bureau of Mines Mineral Industry Surveys.

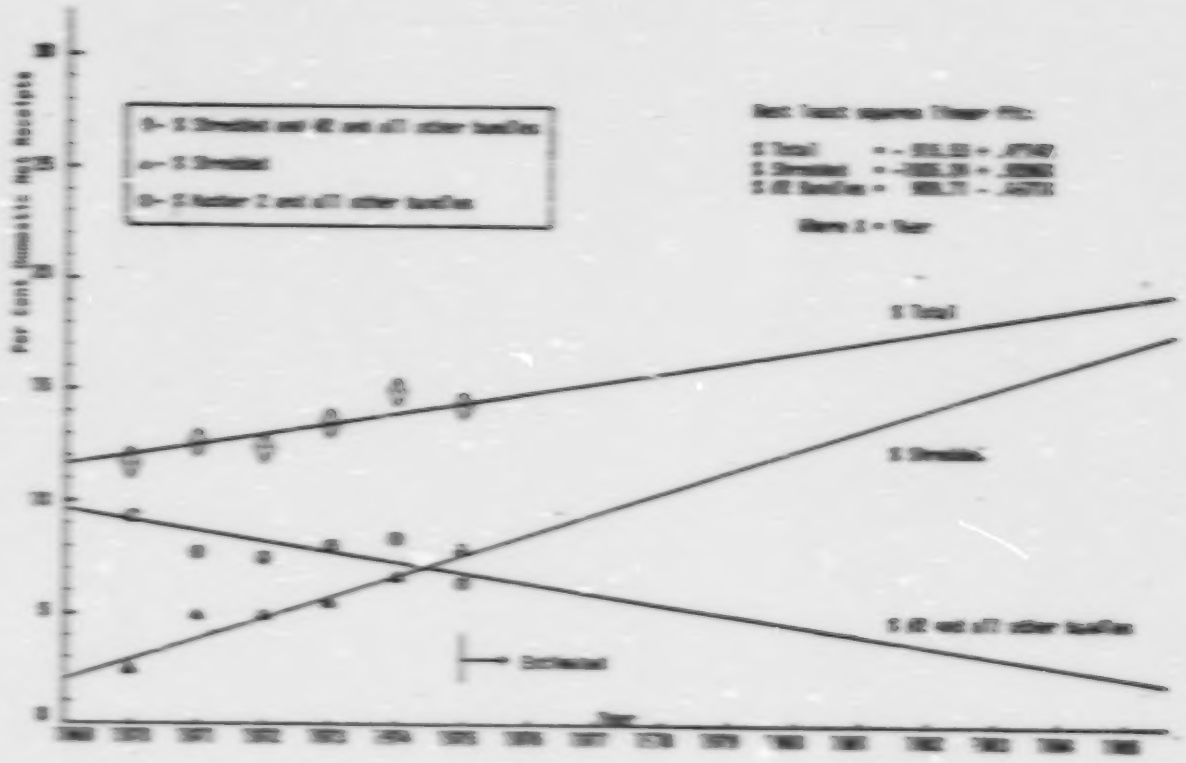


Figure F8. Percentages of Number 2 and All Other Bundles and Shredded Scrap of Net Total Domestic Receipts of Iron and Steel Scrap

will grow faster than number two bundle production which will recede. Both processes draw scrap from about the same sources--primarily automobiles and obsolete consumer durables. Thus it seems likely that the increased upgrading of this source allowed by shredding provides it with a greater proportion of total net purchased scrap. Specifically, the projection line indicates that from 1975 to 1985 the percent shredded of net domestic purchases will rise from 7.6 to 17.6, the percent of number two bundles will fall from 6.9 to 2.0, and the total percentage of the two will rise from 14.5 to 19.4.

Exports of number two bundles and shredded scrap are similarly normalized to total scrap exports in Table F12. The plot and projections are displayed in Fig. F5. The proportion of number two bundles oscillates downward from a value near 20 percent in the midsixties to one between 10 and 15 percent in the early seventies. The shredded scrap fraction again shows a marked growth: it more than doubles from 11.5 percent in 1970 to 26.3 percent in the first quarter of 1975. The annual percentages of number two bundles is projected to 1985 by the best least squares line: the proportion falls from 12.3 percent in 1975 to 7.5 percent in 1985. Since the rate of change of the shredded percentage tends to decline in succeeding years, future proportions were estimated by a curved line with a gradually decreasing slope. This estimate shows the proportion rising from 25 percent in 1975 to 42.3 percent in 1985. As in the case of domestic purchases, the shredded fraction is again expected to rise faster than the proportion of number two bundles falls: the expected percentage of their total grows from 37.6 percent in 1975 to 49.6 percent a decade later.

The simultaneous effects of proportion changes of the two grades of scrap and the varying required quantities of the total net purchases and exports are displayed in Fig. F6. Domestic purchases of shredded scrap are expected to almost triple from about 3.5 million tons in 1975 to about 10 million tons a decade later; domestic purchases of number two bundles diminishes by half in shrinking from about 3 million tons to less than 1.5 million tons in the same time frame. Shredded scrap exports are anticipated to more than double in going from somewhere between 2.2 and

TABLE F12

PROPORTIONS OF #2 AND ALL OTHER BUNDLES AND SHREDDED SCRAP
OF ALL EXPORTS OF U.S. SCRAP
(thousand short tons)

Year	Total Exported	#2 Bundles		Shredded #1/#2		Shredded & #2 % of Total
			%		%	
1960	7,190	1,210	16.8	NA		--
1961	9,713	1,679	17.3	--		--
1962	5,113	1,106	21.6	--		--
1963		1,250		--		--
1964	7,098	1,442	20.6	--		--
1965	6,249	1,450	23.2	--		--
1966	5,880	1,226	20.8	--		--
1967	7,666	1,511	19.7	--		--
1968	6,692	969	14.5	--		--
1969	9,291	1,036	11.2	--		--
1970	10,111	1,381	13.6	1,166	11.5	25.1
1971	6,663	987	14.8	1,026	15.4	30.2
1972	7,683	897	11.7	1,463	19.0	30.7
1973	11,412	1,271	10.7	2,096	18.4	29.1
1974	8,824*	1,304*	14.8	1,909*	22.8	37.4
1975 (1st Quarter)	2,188*	344*	15.9	568*	26.3	42.2

*Preliminary

Source: #2 Bundle Exports 1960-68 from U.S. Bureau of the Census, U.S. Exports, Schedule B, Commodity and Country, FT 410; Total Exports 1960-68 and all other data for 1969-73 from U.S. Bureau of Mines Minerals Yearbook, 1960-72 and "Iron and Steel Scrap" Preprint 1973. 1974-75: U.S. Bureau of Mines Mineral Industry Surveys.

Note: Exports were controlled in latter portion of 1973 and all of 1974.

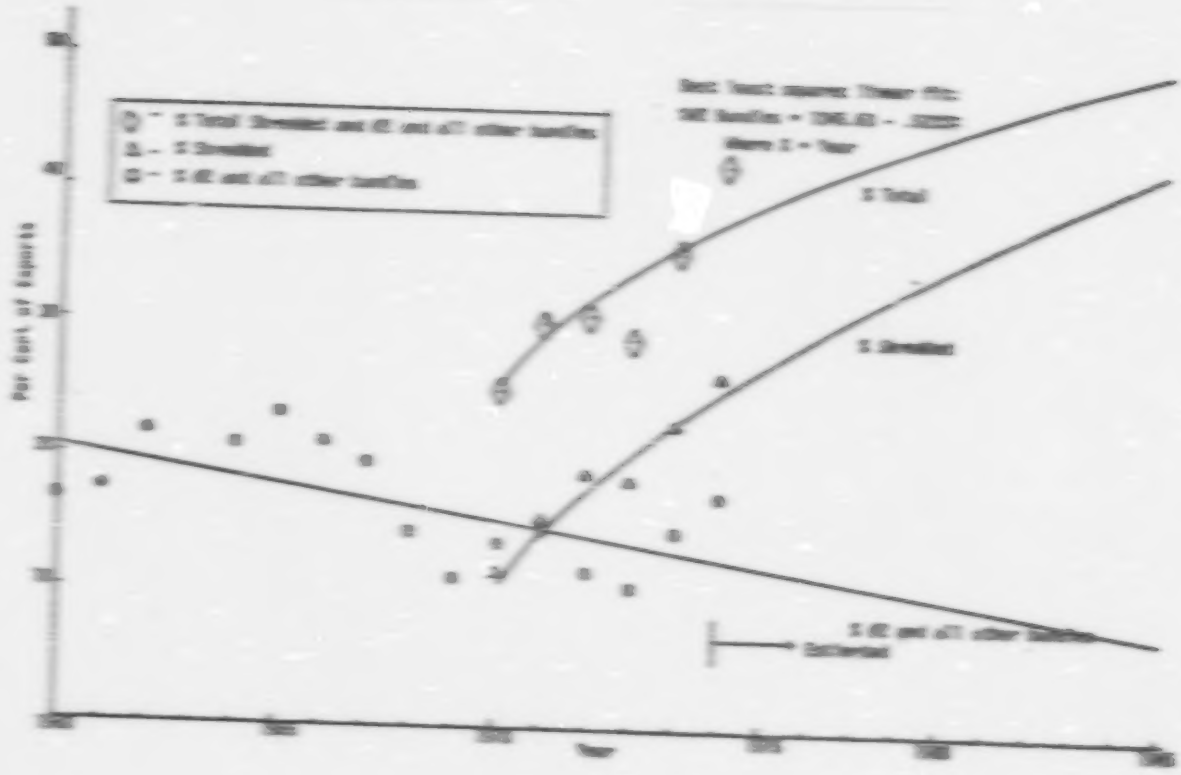


Figure F1. Percentages of Number 2 and All Other Bundles and Shredded Scrap of Exports of U.S. Iron and Steel Scrap

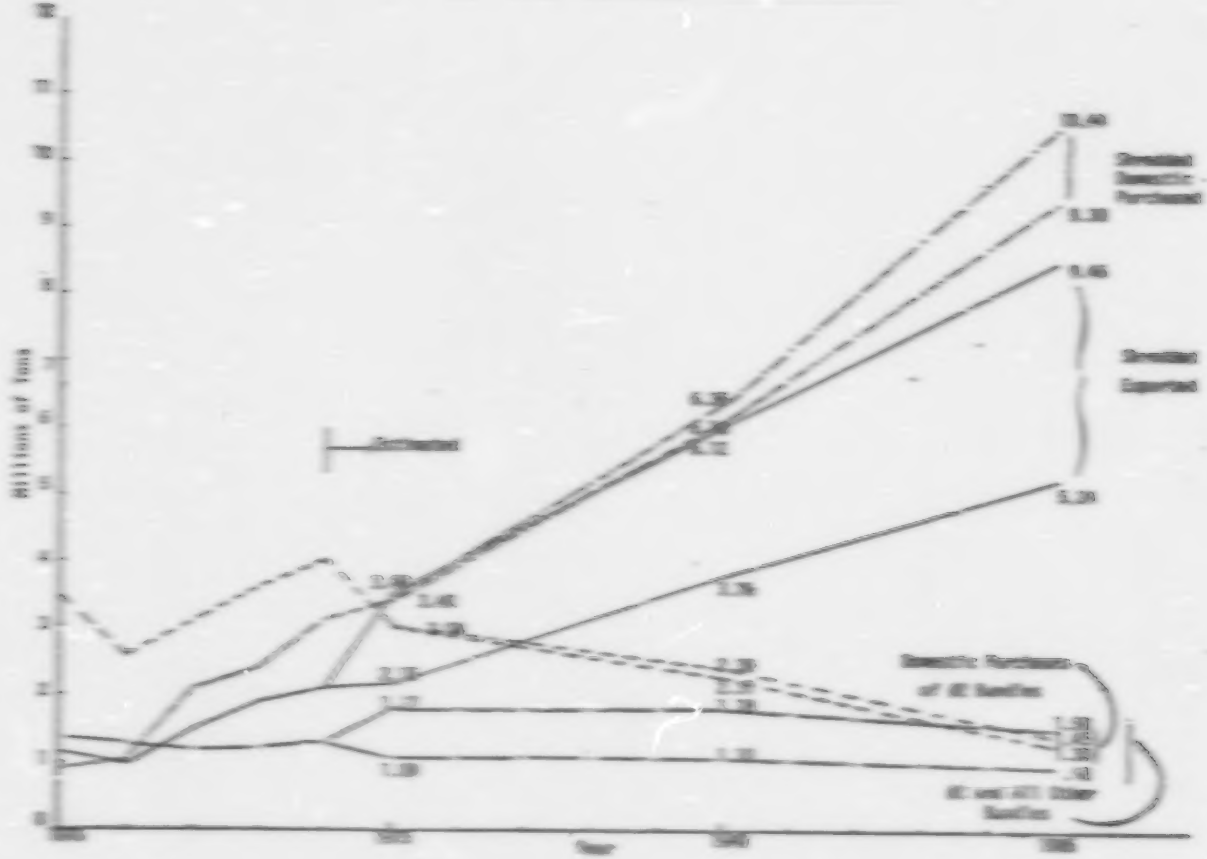


Figure 46. Requirements for Shredded and #2 and All Other Bundled Scrap

3.5 million tons to some annual quantity in the range of 5.2 to 6.5 million tons. Number two bundle exports are projected to diminish insignificantly, remaining between 1.8 and .9 million tons during the 10 year period.

Adjusting the purchased scrap requirement projections to reflect a corresponding total domestic receipts requirement, the actual and projected domestic and export utilization of shredded scrap and number two bundles is listed in Tables F13 and F14, respectively. Using estimates developed in the Booz-Allen study, Table F13 generates an estimate of the tonnage of shredded and slabbed scrap derived from automobiles in the years from 1958-74. Similar estimates are developed for number two bundle scrap in the succeeding table. Assuming that the respective proportions hold in the future, the amounts of automobile scrap recycled in future years is estimated.

F.5 Ferrous Scrap Availability in Deregistered Automobiles

The total amount of automotive scrap from both sources is shown in Table F15. The number of vehicles processed that this scrap represents is computed. The difference between this and the annual retirement figures is shown in the final column. The data for 1958-69 is exactly that given by Booz-Allen except for some minor refinements in the retired vehicle figures given in a more recent (1974) edition of Wards' Automotive Yearbook. There is a substantial difference between these estimates for 1970 and the last year analyzed in the Booz-Allen study, again due to a retired vehicle number which is about 1.5 million automobiles less in the most recent calculation given by Wards'. Automobile retirement estimates for 1974-85 are obtained from a recent study noted with the compilation in Table F15. The difference between the number of vehicles processed and retired in a given year is shown in Figure F7. Note that after 1973 more cars are processed than retired by using either the high or low estimate.

The net accumulation of retired vehicles is presented in Figure F8. The estimate band indicates that the total accumulation of unprocessed

FOOTNOTES TO TABLE F13

[a,b] 1971-72: U.S. Bureau of Mines Minerals Yearbook, 1971-72. 1973: "Iron and Steel Scrap" Preprint 1973. 1974: U.S. Bureau of Mines Mineral Industries Survey (preliminary data). Projections 1975-85 from graph 5. Purchased Scrap is considered to be essentially equal to Domestic Receipts in case of Shredded Scrap.

[c] 1965-70: Booz-Allen estimate based on consultation with experts in scrap processing industry. 1971-85: sum of Dealers' Receipts and Exports.

[d] 1965-70: Booz-Allen estimate in consultation with scrap processing experts. This value is assumed to hold for latter years.

[e] 1950-64: Booz-Allen estimate in consultation with scrap processing experts.

[f] 1950-64: High estimate = 70% column e, low estimate = 82.5% column e. 1965-85: Low estimate = 70% lowest estimate column c ÷ 100% column e, high estimate = 82.5% highest estimate column c ÷ 100% column e. Booz-Allen estimates for period 1950-70: The 70% and 100% obtained in consultation with scrap processing industry personnel. The 82.5% figure obtained from Bureau of Mines Survey of nine representative shredding operations released July 15, 1971. The projections for 1975-85 based upon continuation of 1965-70 shredder input ratio from automotive sources.

[g] Estimated on basis of actual Dealer/Total Receipts ratio of .933 for 1974.

[illegible]

[illegible]

[illegible]

FOOTNOTES TO TABLE F14

a,b 1958-72: U.S. Bureau of Mines, Minerals Yearbook, 1958-1972, "Iron and Steel Scrap" Preprint 1973. 1974: Minerals Industry Survey "Iron and Steel Scrap" with estimates as indicated. Projection 1975-85 from Graph G. For projection years, domestic receipts figured at 103% purchased total on basis of 1972-74 average.

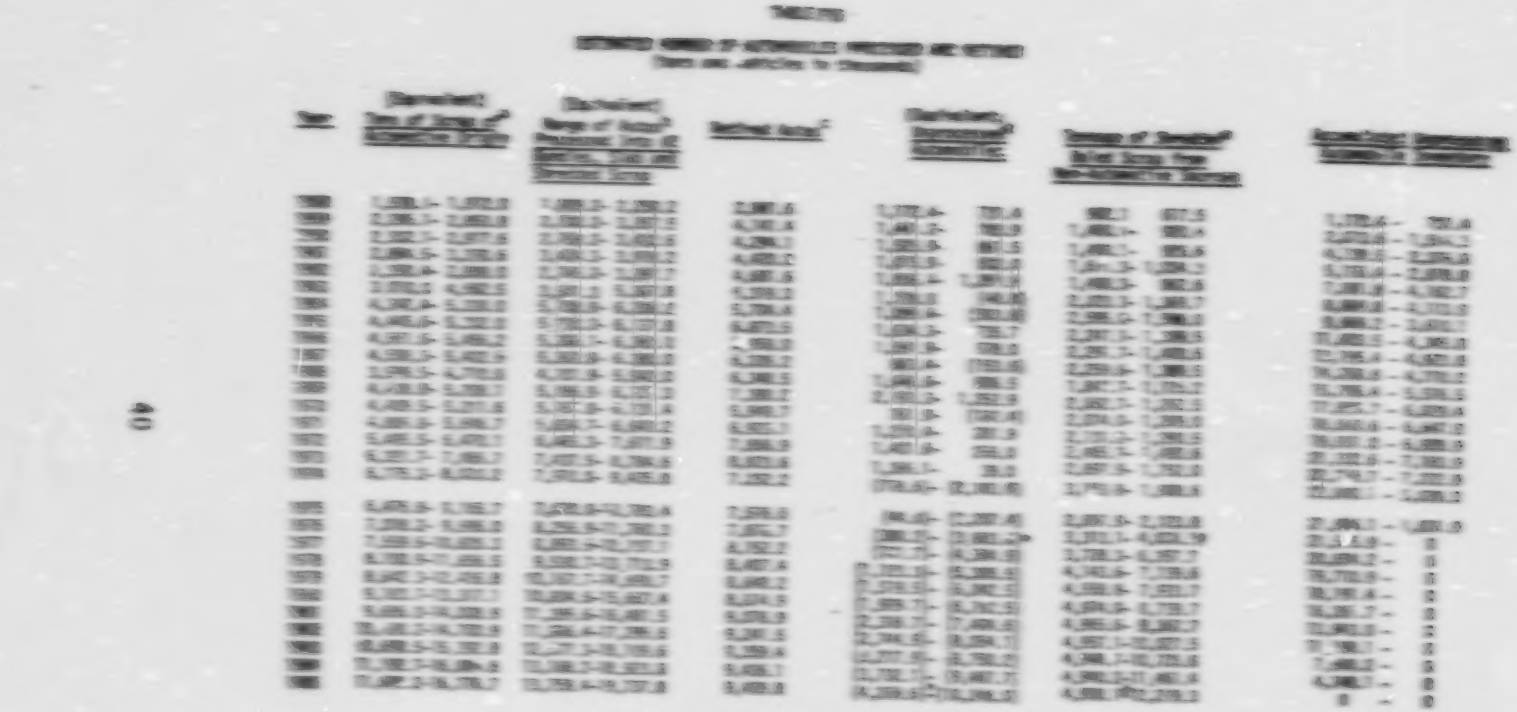
c Booz-Allen estimate that 90% of #2 and All Other Bundles attributable to #2 Bundles 1958-70. Estimate assumed to hold for latter years.

d U.S. Bureau of the Census, U.S. Exports, Schedule B, Commodity and Country, FT 410. 1970 figures are from U.S. Bureau of the Census, Tailor Made Statistics, FT 410, "Iron and Steel Division". 1971-73: U.S. Bureau of Mines, Minerals Yearbook, 1971-72, Preprint 1973. 1974: Minerals Industry Survey (Preliminary Data).

e Booz-Allen in consultation with Mr. William Story of Scrap Iron and Steel Institute estimated: 1) the % of impurities in #2 Bundles at 14%. 2) The % of automotive scrap in #2 Bundles at between 60 and 75%. Therefore, low estimate = (.86) x (.60) x (column D and column C); and high estimate = (.86) x (.75) x (column D and colum C). For projections, lowest estimate is based on lowest projection and highest estimate is based on highest projection.

* Estimate based on linear regression method applied to actual 1963-67 data by Booz-Allen.

Estimate based on actual data 1963-67, 1974 using linear regression method.



FOOTNOTES TO TABLE F15

[a]Add column f, Table 13 and column e, Table F14.

[b]Using Booz-Allen estimate of 1700 lbs of ferrous scrap output per hulk for entire period.

[c]Wards Automotive Yearbook (1974) for years 1958-72. 1973-85 projections from IR&T The Automobile Study for Business International--Scenario I.

[d]Column c - column b.

( ) Indicates negative number.

*Inventory depleted on this year. After depletion figures represent equivalent automobiles.

#Indicates year in which inventory is depleted and tonnage for equivalent unprocessed autos must begin to be made up from nonautomotive sources.

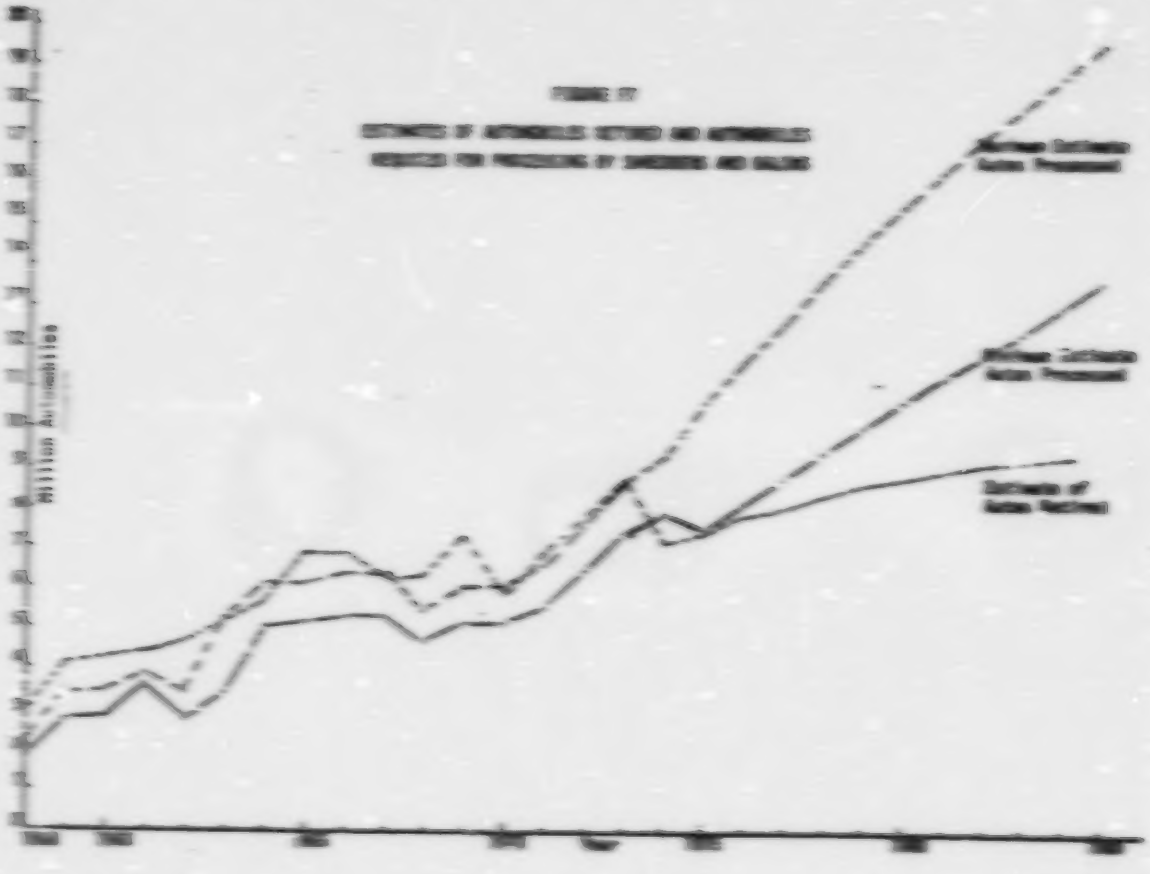


Figure 17. Estimates of Automobiles Retired and Automobiles Required for Processing by Shredders and Balers

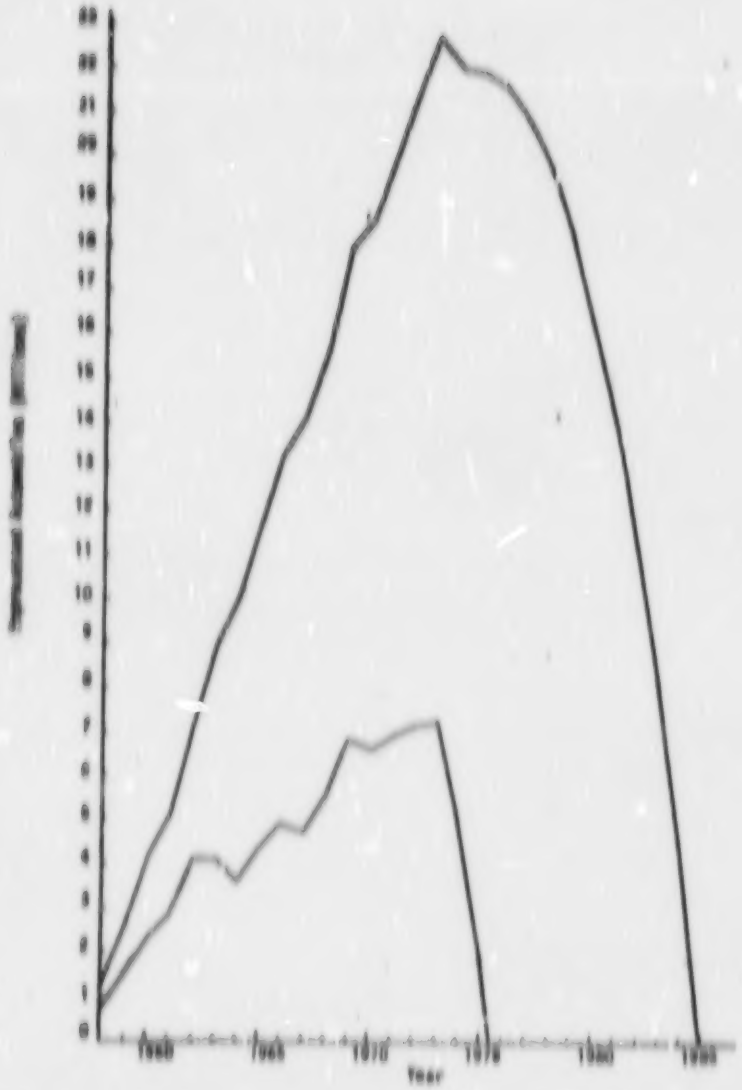


Figure F8. Cumulative Unprocessed Automobiles

cars will be exhausted sometime between 1976 and 1985. A best estimate given this wide uncertainty band would place the time of total depletion in 1980. If the simplistic view is adopted that the previously identified proportions of number two bundles and shredded scrap attributable to automobiles is maintained as long as unprocessed cars are present, these proportions will of necessity decrease after this depletion date.

Since it seems very likely that the backlog of unprocessed automobiles will be exhausted by 1980, it is more realistic to analyze the supply and requirement information in terms of tonnage when estimating the effects of the changing materials composition in automobiles. The entire shortfall as well as any increment due to steel reduction then can be expressed in terms of tons rather than cars that would have been processed.

Renner estimates that the amount of steel in a composite 1975 new car to total 2102 pounds. In the most probable case, he predicts that this will decline to 1600 pounds in 1980, and 1368 pounds in 1985[23]. This development will reduce the amount of ferrous scrap available to the shredding and baling industry below the level estimated in the previous section where the steel content of vehicles was assumed to remain constant.

The changing compositions of new cars will not impact upon the scrap industry until these cars are retired and become available as scrap. Thus the problem of estimating the changing composition of a composite retired car presents itself. The amount of steel in this composite retired car is a weighted average of the quantities of steel present in the composite cars from model years that are retired in a given year. The weighting is based upon the proportion that cars from a given model year are of the total number of cars retired in that year.

This effect can be quantified by considering the data in Tables F16 and F17. The Bureau of Mines composite car from 1954-65 contained 2532 pounds of steel. The 1969 NAAO composite contained 2302 pounds of steel.[24] In Table F17, an average composite value of 2400 lbs was assumed for the entire period through 1970. The Renner estimates are shown for

TABLE F16
STATISTICAL DATA ON AUTOMOBILE SURVIVAL

Year n	Probability that a car will survive its nth year	Probability that a car will be taken out of registration in year n
1	0.984[1]	0.016[2]
2	0.968[3]	0.016[1]
3	0.951	0.017
4	0.932	0.019
5	0.905	0.027
6	0.876	0.029
7	0.811	0.065
8	0.729	0.083
9	0.607	0.122
10	0.483	0.124
11	0.362	0.121
12	0.278	0.084
13	0.209	0.069
14	0.156	0.053
15	0.115	0.041
16	0.087[3]	0.028[3]
17	0.0655[3]	0.0215[3]
18	0.0491[3]	0.0164[3]
19	0.0367[3]	0.0124[3]
20	0.0272[3]	0.0095[3]

Source: Motor Vehicle Manufacturers Association of the U.S., Inc., *1972 Automobile Facts and Figures* (Detroit, Michigan: Motor Vehicle Manufacturers Association of the U.S., 1972).

[1] All data averages for production from 1943 to 1966.
[2] Estimates.

1975, 1980, and 1985. Quantities between these years are interpolated. Anticipated new registrations for each year are also shown. The probability that a car will be retired n years after it is registered is shown in Table F16. This information together with the annual anticipated retirement figure presented in Table F15 allows the calculation of the steel composition of a composite retired car in year t in accordance with the following equation:

$$(SW)_t = \frac{1}{R_t}\left[P_1(NR)_t(NW)_t + P_2(NR)_{t-1}(NW)_{t-1} \right.$$

$$\ldots\ldots P_{(t-1970)}(NR)_{1971}(NW)_{1971} +$$

$$\left. (R_t - \sum_{1}^{t-1970} P_1(NR)_{(t+1-1)})\ (2400)\right]$$

where:

$(SW)_t$ = Composite steel weight of a retired car in year t;
R_t = Number of cars retired in year t;
$(NR)_t$ = Number of new registrations in year t;
$(NW)_t$ = The composite steel weight of a new car in year t;
and P_n = The probability that a car will be taken out of registration in year n.

Values were computed for 1975, 1980, and 1985. Steel quantity in intervening years was obtained by interpolation. The results are given in Table F17. Though the composite retired car during the period examined in the Booz-Allen study contained 2400 lbs. of steel, only 1700 lbs. was thought to pass through the baling or shredding route for recovery. Thus the scrap availability to a baler or shredder represented by future composite retired vehicles was assumed to be (1700/2400) = .708 of the total steel present in the automobiles. The final scrap availability to the baling and shredding industry in the base case of no steel reduction and in the case of the Renner prediction is presented in Table F17.

The annual availability of scrap from automobiles to balers and shredders is plotted on Figure F9. An estimate of their minimum and maximum requirements for scrap from this source on the basis of past input proportions is also presented. Annual shortfalls accrue after 1973. Estimates from the previous section suggest that under the assumed conditions the backlog will vanish between 1976 and 1985, with a best estimate being 1980. When the anticipated materials changes are factored in, no change is anticipated in the earliest possible depletion date since most cars processed prior to that year will have been manufactured before 1970. The latest possible depletion date is affected; however, this is moved forward to late 1983 or early 1984. A best estimate would then probably be 1979 for depletion of the backlog of unprocessed retired automobiles.

By this time it is apparent that the original assumption positing that automotive scrap would continue to account for the same proportion of the scrap feed to the baling and shredding industries is untenable. Even the attempted refinement which supposed that this remained true until the inventory was completely depleted is not very good. No doubt the portions of automotive scrap will not change abruptly at the time of depletion, but rather decline in some unquantifiably more gradual manner. Though depletion may not end abruptly, it certainly could be assumed to be essentially complete by 1985. This suggests an interesting by-product of these projections. At that time, the requirement lines in Figure F9 represent a proportion of automobile input to the auto scrap processing industry that was ascertained by Booz-Allen in 1973; automotive input to balers was 60-72% and to shredders was 70-82.5%. In the case of constant car composition, scrap availability from cars in that year will be between 50 and 70 percent of the 1973 proportions. If balers and shredders share the shortfall proportionately, automotive scrap input to balers will be between 30 and 50 percent of the total, and that to shredders will be between 35 and 55 percent of the total. When materials changes are taken into account, the automotive scrap input to balers in 1985 is anticipated to be between 20 and 43 percent, and that to

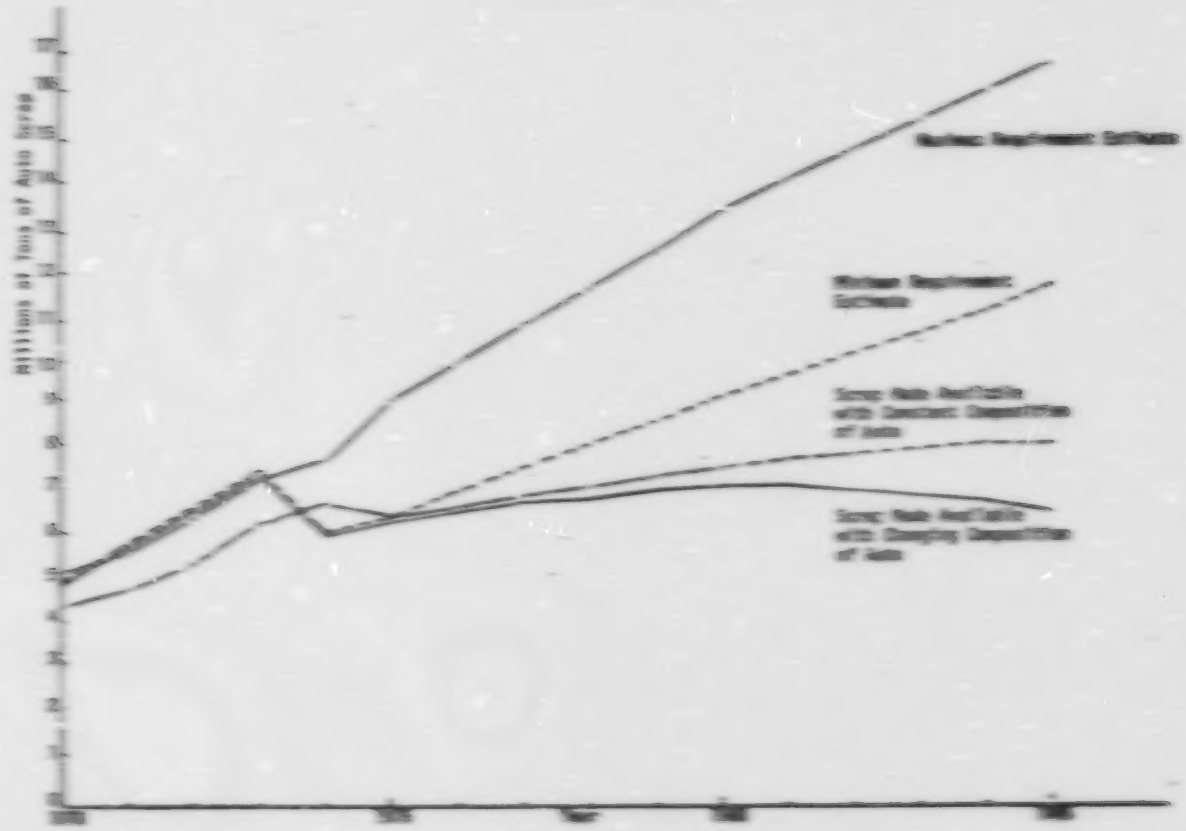


Figure F5. Unregistered Automobiles: Scrap Availability to and Scrap Requirements of Balers and Shredders

shredders is expected to be between 28 and 47 percent.

These estimates are made assuming that shredders do not completely dominate automobile scrap such that no cars are processed through the baling route.

If this situation were to occur by 1985, balers would have none of their input derived from automobiles. The resulting increase in automotive input to shredders would be between .9 and 1.3 million tons in the case of changing materials composition. Automobiles then could account for between 40 and 57 percent by weight of all ferrous input to shredders.

F.6 Summary

This investigation of automobile recycling from the viewpoint of future ferrous scrap requirements and automotive scrap availability suggests that:

1. beginning in 1974, more cars have been and will be processed than are retired annually;
2. in the case of constant automobile composition, the backlog of unprocessed, deregistered automobiles will be effectively depleted sometime between 1976 and 1985, with 1980 being a best estimate;
3. in the case of changing automobile composition, the backlog will be depleted sometime between 1976 and 1983-4, with 1979 being a best estimate;
4. assuming that this backlog is eliminated by 1985, in the case of constant car composition, automobiles will be able to provide 30-50 percent of the input to balers, and 35-55 percent of the input to shredders at that time;
5. making the same assumption in the case of changing car composition, deregistered automobiles can provide 20-43 percent of the input to balers, and 28-47 percent of the input to shredders;

and,

6. assuming further that all automobiles are processed by shredders in 1985, this source can provide 40-57 percent by weight of all ferrous inputs to shredders.

The results that this analysis suggests obviously cannot be treated as conclusive. The dynamics of the process that translates scrap demand into recycled automobiles have been ignored. For instance, it was estimated in the Booz-Allen study that about a fifth of the unprocessed inventory was due to abandoned automobiles. Processors may turn to alternative scrap sources before attempting to utilize that portion of the backlog attributable to effectively inaccessible abandoned automobiles. This portion of the accumulated inventory may never be processed without outside intervention. The immediate predictive power of these results thus must be diminished by the possibility of interference by specific bottlenecks (the abandoned car problem is probably the greatest concern in this regard) in the process that links demand and availability.

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APPENDIX G

DEMAND, AVAILABILITY, AND PRICE OF STEEL AND SUBSTITUTE MATERIALS FOR AUTOMOBILE MANUFACTURE

by A. Watson

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6.1 Introduction

This paper analyzes the economic impact of materials substitution in the alternative designs of the automobile of 1980 and 1990 given by Renner in an earlier appendix written for this study.[1] The demand, availability and price of ferrous metals (iron and steel), aluminum, and plastics, the materials significantly affected by the substitutions, are analyzed in an attempt to show the comparative economic advantage of substituting one material for another.

This paper first analyzes automobile demand for the substitute materials and the projected demand created by the alternate designs. Several questions are then raised from this analysis. Is there an adequate supply and capacity to meet the projected levels of demand and at what cost? Which design will be most competitive economically? The proceeding sections will attempt to address these questions in a discussion of material availability and price. A comparison of each design at projected prices will then be made to show which design is most economically rational.

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[1] Roy Renner, "Future Material Competition in Automobiles", Appendix A

6.2 Automobile Demand for Substitute Materials

An analysis of the current demand for iron, steel, aluminum, and plastics by the automobile industry, based on data gathered from various Government agencies and trade associations, indicated that only consumption of iron and steel was significant, reflecting their prevalent use in the automobile (77.5% of the total weight of the 1975 model year composite automobile). As can be seen in Table 61, the automobile industry consumed 21% of all steel and 46.8% of all malleable iron produced in the US in 1973. The latest available data for gray and ductile iron was in 1969, when it constituted 17.1% of total US consumption.[1] The demand for plastic and aluminum has remained nominal, reflecting their limited use (3.5% and 3.0% respectively of the weight of the 1975 model year composite automobile). In 1973, automotive demand was 4% of total US consumption of plastic and 8% of total US consumption of aluminum. However, automotive consumption of certain plastic types is often quite significant as can be seen from Table 62 with consumption of nylon, polyacetal, polyurethane, and thermoplastic polyester ranging from 15 to 57% of total US consumption. A significant proportion of aluminum used in the automobile is derived from secondary sources. According to a Chrysler Corporation report, the company uses secondary sources for nearly all of its die cast aluminum parts, which constitute 75-80% of aluminum in the automobile.[2]

Under the Renner alternative designs for 1980 and 1990, iron and steel will be increasingly replaced by plastics and aluminum, reflecting the trend toward lighter and more fuel-efficient vehicles in response to the energy crisis. For example, the use of steel will drop from 61.2% of the total vehicle weight in 1975 to 44% of the 1990 maximum credible aluminum content B-size (2500-4000 lbs.) compact. Iron drops from 4.5% in 1975

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[1] Automobile Facts and Figures, 1970 Edition, Motor Vehicle Manufacturers Association.

[2] "Energy in the Automobile," presentation by Doran E. Samples, Chrysler Corporation, p. 20.

TABLE 61

MATERIALS CONSUMPTION BY THE AUTOMOTIVE INDUSTRY
1973

MATERIAL	AUTOMOTIVE CONSUMPTION (1000 Metric Tons)	TOTAL CONSUMPTION (1000 Metric Tons)	% TOTAL CONSUMPTION
Steel - Vehicles	13,614		13.4
Parts & Accessories	7,445		
Total Steel	21,059	101,070	20.8
Malleable Iron	437	934	46.8
Gray & Ductile Iron[1]	2,467	14,451	17.1
Total Ferrous Metals	23,963	116,455	20.6
Aluminum	520	6,601	7.9
Plastics	677	13,152	4.4

[1] Estimate based on 1969 level, latest available data.

SOURCES: 1. Steel: American Iron and Steel Institute (AISI).
2. Malleable Iron: Motor Vehicle Manufacturers Association.
3. Gray & Ductile Iron: Automobile Facts & Figures, 1970 Motor Vehicle Manufacturers Association.
4. Aluminum: Mineral Facts & Problems, 1974 U. S. Bureau of Mines.
5. Plastics: Modern Plastics, January 1975

TABLE 62

AUTOMOTIVE CONSUMPTION OF PLASTICS BY TYPE
1973[1]

MATERIAL	WEIGHT (1000 Metric tons)	% /OTAL US CONSUMPTION
ABS	69.0	14.7
Acrylic	14.4	6.8
Cellulosics	8.7	11.3
Nylon	14.6	17.0
Phenolic	23.0	3.7
Polyacetal	4.6	18.3
Polycarbonate	1.6	3.2
Polyethylene, high density	20.0	1.6
Polyethylene, low density	2.0	.1
Polypropylene and copolymers	90.0	6.9
Polystyrene, high-impact	5.0	.6
Polyvinyl chloride	110.0	5.1
RP (polyester/glass)	79.0	12.6
Polyurethane	195.0	21.1
SAN (Styrene-acrylonitrile)	4.6	8.2
Thermoplastic polyester	5.5	57.3
Epoxy	3.7	6.6
Other[2]	11.3	-
Total	577.0	4.4

[1] Based on data for 1974 Model Year passenger car

[2] Includes alkyds, fluoroplastics, melamine, noryl phenylene oxide-based resin, polysulfone, etc.

SOURCE: Modern Plastics, January 1975

to 2.6% of the 1990 maximum credible aluminum C-size (under 2500 lbs.) subcompact. In the maximum credible plastic case, plastic rises from 3.6% in 1975 to 17.7% in 1990 (B-size compact).

In order to measure the economic impact of these substitutions, it was necessary to make an estimate of passenger car production for 1980 and 1990. There were 9.7 million cars manufactured in 1973. In 1974 only 7.3 million cars were produced. In 1975, it is expected that only 6.6 million passenger cars will come off the assembly lines, reflecting the energy crisis and recession in which the automobile industry was particularly hard hit. In light of the decreases in recent years, projections of automobile production have been less optimistic than previous estimates. D.O.T. (Department of Transportation) has projected that production plus imports would be 12.2 million in 1980 and 14 million in 1990. Other estimates have been more conservative. R.U. Ayres, in a forthcoming IR&T study on the motor vehicle industry, projected total new registrations in 1980 (domestic sales plus imports) to be 10.9 million and in 1990, 12.7 million.[1] For the purposes of this analysis, it was estimated that 10 million cars would be produced in 1980 and 12 million in 1990. These estimates are comparable to those of D.O.T., and assume that imports will remain at 15 to 16%, which is the level they have maintained in recent years (1970-74). This year, however, they have been averaging 20% during the first 6 months. Whether or not this will become a trend remains to be seen. Imports may constitute a larger share of the US market than projected. One reason for this may be a conscious policy by the American corporations, which may find it economically desirable to allow their foreign subsidiaries to produce smaller cars overseas because of high US labor costs.

One more step was necessary in order to translate the Renner projections made by car into total demand for materials. That was to

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[1] R.U. Ayres, The World Motor Vehicle Industry to 1995.

estimate the prompt scrap generated in the manufacture of automobiles. Because data on scrap generation by product category is generally difficult to obtain, most estimates made in recent years have represented an overall industry average for the material. The following percentages were used: 20% of steel mill products and 5% of iron castings (derived from the Battelle-Columbus study, Identification of Opportunities for Increased Recycling of Ferrous Solid Waste), 16% of aluminum products (based on Minerals Yearbook data for the amount of new scrap consumed), and 6% of plastics production (based on Arthur D. Little's study, Incentive for Recycling and Reuse of Plastics, PB 214045, 1972).

As can be seen from the results listed in Table 63, automotive demand for steel drops 30-40% in 1980 and for iron 35-60% in 1980 and 60-80% in 1990, depending on design. Significant increases in plastic and aluminum demand are projected for all alternative designs with the use of plastic increasing ½ to 4 times the level in 1973, and aluminum, ½ to 7 times. Much of increased demand for aluminum will be met from primary sources, with a greater use of sheet (rolled/drawn) aluminum expected in the body.[1] The demand for primary and secondary aluminum is presented in Table 64. Whether or not there will be an adequate supply and capacity of aluminum and plastics, particularly under their respective maximum credible designs, and at what price will be analyzed in the next section on limitations.

[1] See T. Jones' Appendix E, "Energy Consequences."

[redacted]

[redacted]

(Thousand Metric Tons)

MATERIAL	1972	1980 Reference Case			1990 Reference Case		
		Recy. Possible	Reference Case Ductile Aluminum	Reference Case Ductile Plastic	Recy. Possible	Reference Case Ductile Aluminum	Reference Case Ductile Plastic
Steel	73,574	9,563	6,707	6,680	9,658	7,429	6,580
Iron	2,894[1]	1,838	1,738	1,804	1,326	539	1,326
Ferrous Metals	76,470	71,501	8,845	72,504	71,556	7,968	8,226
Aluminum	520	555	1,009	851	2,007	3,655	1,329
Plastic	577	655	862	1,264	1,407	1,942	2,326

[redacted]

[1] Estimate

TABLE 64

AUTOMOTIVE DEMAND FOR PRIMARY AND SECONDARY ALUMINUM[1]

1985	Most Probable Materials Contents (1000 Metric Tons)	Maximum Credible Aluminum (1000 Metric Tons)	Maximum Credible Plastics (1000 Metric Tons)
Primary	(29.0%) 293	(45.0%) 830	(36.7%) 513
Secondary	(70.0%) 706	(54.1%) 979	(63.3%) 840
Total Aluminum Demand	999	1809	853
1990			
Primary	(44.5%) 899	(54.5%)2013	(37.6%) 575
Secondary	(55.5%)1122	(45.4%)1677	(62.4%) 954
Total Aluminum Demand	2021	3693	1529

[1] See T. Jones' Appendix E, "Energy Consequences", p. 3.

6.3 Limitations: Availability and Price of Substitute Materials

The earth is abundant in natural resources. The major constraints upon their availability are economic and technological. Two of the materials under consideration, iron and aluminum, are exceptionally abundant in crystal rock, which has an average composition of 8% aluminum and 6% iron.[1] For these readily abundant materials, a slight rise in their price would enable a significantly higher amount of ore to be economically recoverable and thus available as reserves. As reserves approach exhaustion, the price of the metal will rise and additional ores would then become economically recoverable. This principle applies to iron and aluminum and states that it would not be possible to exhaust them in the foreseeable future.

[1] Noble, S.R., "Resources and the Political Options Facing the United States," Isolation of Interdependence? Today's Choices for Tommorrow's World, M.A. Kaplan, ed., University of Chicago Center for Policy Study, 1975.

G.3.1 Availability

1. Aluminum

Aluminum is one of the most abundant metallic elements in the earth's crust. At present, technology and price have limited its reserves to bauxite. US bauxite resources are located in Arkansas and are estimated by the US Bureau of Mines to be about 45 million metric tons. An additional reserve of one million tons in Alabama and Georgia is being mined for specialty uses. Over the past decade, domestic mine output has ranged from 374,000 to 486,000 metric tons per year (aluminum content). The United States is the largest producer of aluminum metal, producing in 1973 42% of world production while it supplied only 7% of its aluminum raw materials requirements from domestic sources, that is, from domestically mined bauxite, stocks, and secondary recovery of old scrap. The United States imports the rest of its raw material requirements: 90% of its domestic requirements for bauxite, 35% of alumina, and 10% of aluminum metal in 1973. The principal suppliers of bauxite were: Jamaica (51%), Dominican Republic (7%), Surinam (22%), and Guyana (11%). Principal suppliers of alumina were: Australia (57%), Jamaica (27%), Surinam (11%), and others (5%). Suppliers of aluminum metal were: Canada (85%), Ghana (8%), and others (7%).[1] The reason the United States imports most of its aluminum requirements is economic, with bauxite from foreign sources less expensive to recover than most aluminum-bearing ores available domestically.

The US industry has been producing aluminum from increasingly lower grade material, including clay that occurs with the bauxite in Arkansas. The estimated reserves have remained more or less constant for several decades, although production of about 400,000 tons has been continuous for many years. The US reserve of bauxite has been estimated to be

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[1] Critical Materials: Commodity Action Analysis, Office of Minerals Policy Development, US Dept. of the Interior, March, 1975.

11.6 million tons (aluminum content) since 1968.

The ultimate aluminum resource is expected to be clays of the kaolin type, anorthosite, and alunite. If improved technology for their processing is forthcoming, dependence upon them as the basic source of aluminum should increase. The United States has large supplies of these materials which could meet all or most of its raw material needs indefinitely. The potential resources of bauxite in the United States are chiefly in (1) large low grade bauxitic clay deposits in Arkansas, Alabama, and Georgia, (2) ferruginous bauxite deposits in Oregon and Washington, and (3) deposits of low-grade ferruginous bauxite deposits in weathered basalts on Kauai and Maui, Hawaii. Commercial recovery of aluminum from these potential bauxite resources awaits development of improved mining and processing technology, an increase in aluminum price, or a combination of these factors. An additional 70 million tons of aluminum are estimated by the Bureau of Mines to be potentially recoverable from the ferruginous and other low-grade bauxites, as can be seen in Table 65.

According to a study prepared for the Bureau of Mines, it would take up to 5 years for the industry to respond economically to a higher price level. Under a stepped-up investment program, capacity to produce aluminum from domestic sources could then be expanded at a rate of 450,000 metric tons of aluminum per year. It would thus take up to 10 years to be able to produce from domestic raw materials and scrap, the current 5.2 million tons of annual aluminum production starting from the present 1.4 million tons capacity, as estimated by the Bureau of Mines. (1,200,000 tons additional capacity at higher prices plus 200,000 tons capacity for secondary recovery and 3,600,000 tons additional capacity at higher prices plus 200,000 tons additional capacity for secondary recovery).[2] With a projected increase in demand for aluminum, national self-sufficiency would take somewhat longer. Aluminum resources are extremely abundant and can be expected to meet US and world demand in the foreseeable future.

[1] See discussion of the Charles River Associates study, An Economic Analysis of the Aluminum Industry, in Critical Materials: Commodity Action Analysis, p. 25.

[2] Ibid., pp. 25-27.

TABLE 65

ALUMINUM RESOURCES (BAUXITE) RECOVERABLE AT VARIOUS PRICES

(MILLION METRIC TONS ALUMINUM CONTENT)

	Price, Constant 1972 Dollars Per Pound Primary Aluminum Metal			
	0.23[1]	0.29	0.33	0.36
North America:				
United States:				
Arkansas	9.3	10.9	13.6	22.7
Southeastern States, Hawaii, Oregon and Washington	3	6.3	20.0	59.0
Total	9.6	17.2	33.6	81.6
Carribean Islands:				
Dominican Republic and Haiti	14.2	14.5	25.4	16.3
Jamaica	204.1	208.6	207.7	244.9
Total	218.3	223.1	233.1	261.2
Rest of World:	3025.4	3385.5	3532	4054.4
World Total:	3243.7	3408.6	3765.1	4725.6

[1] US average price in 1972

Source: Mineral Facts and Problems, US Bureau of Mines

TABLE 66

PROJECTED PRIMARY ALUMINUM CAPACITY
(Thousand metric tons)

	1973	1974	1980	1990
Primary Aluminum Capacity				
US	4438	4451	5170	
Rest of World	9205	9267	12371	
Demand for Primary Aluminum Created by Former Maximum Creditable Aluminum Car			830	2813

Source: Mineral Facts and Problems, US Bureau of Mines.

Source: Post Office Department Annual Reports, 1972 to 1980, and Postal Research Institute.

Primary aluminum capacity as projected by the Bureau of Mines for 1980 is more than sufficient to meet demand created by Renner's alternative designs as can be seen in Table 66. Projections of capacity beyond 1980 are speculative at best. However, as stated before, availability of aluminum is virtually unlimited if the price is high enough.

For secondary demand, forecasts made by SEAS solid waste module and MRI (Mid-West Research Institute) of secondary aluminum availability as shown in Table 67 will be greater than the tables indicate because of the increased production of primary aluminum resulting from the alternative designs.

2. Iron

Iron-bearing substances are abundant and widely-distributed throughout the world. US mine output of iron ore during the past decade ranged from 42 million metric tons in 1963 to 54 million tons in 1969-70. Average annual output for the 10-year period was 50 million metric tons, equivalent to approximately 47 percent of average total domestic demand and 68 percent of average US primary demand. The United States share of world mine production in 1973 was 10.3% and for pig iron production, 18.2%. Imports of iron ore in 1973 were equivalent to 30 percent of total consumption (mainly from Canada, Venezuela, and Liberia). Less than 1% of the US requirements for pig iron were imported.

The domestic reserves of 2 billion metric tons iron in ore are located in the Lake Superior region on the Mesabi range in northern Minnesota (low-grade ores of taconite type). The Bureau of Mines estimates that potential resources of an additional 14.5 billion metric tons would be available if the price were to increase by $6 per ton as can be seen from Table 68.

Ore production could be increased to meet total domestic primary need, with a relative sacrifice in quality, or increase in cost over imported ore. All raw material inputs will be in adequate supply in the foreseeable future. Projected expansions of iron ore industries in Canada, Brazil, and Australia are expected in the near future to meet increased world demand.

TABLE 10

WORLD IRON RESOURCES (IN IRON ORE)

RECOVERABLE AT VARIOUS PRICES

(MILLION METRIC TONS IRON CONTENT)

	Price, Constant 1972 Dollars Per Short Ton of Primary Iron Contained in Ore		
	17.60[1]	28.80	33.60
North America:			
United States	7000	2400	16300
Canada	10600	13200	26300
Other[2]	400	300	—
Total	12900	16700	42600
Rest of World:	74900	100900	144200
World Total:	87700	117600	186800

[1] Year end price, 1972 US shipment (at mines).

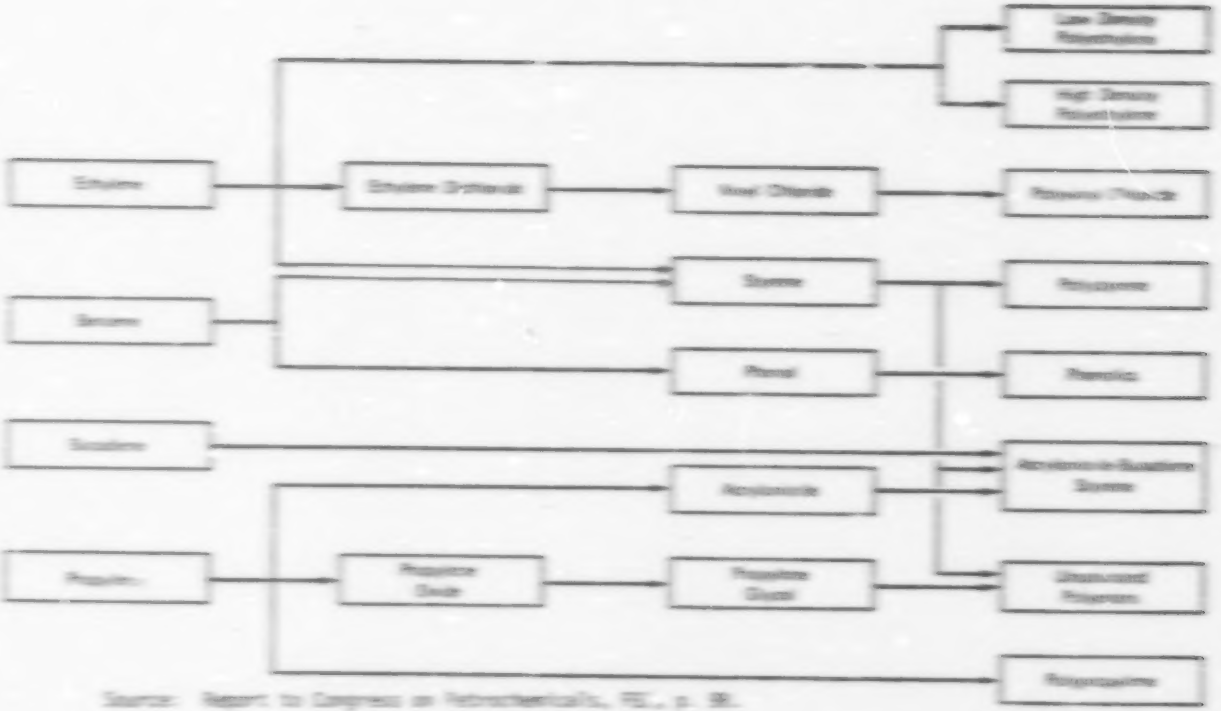
[2] Including Mexico, Central America and Puerto Rico.

Source: Bureau of Mines assessment in Mineral Facts and Problems.

3. Plastics

Availability of raw materials for the production of plastic materials and resins is difficult to analyze because of the complexity and variety of plastics which are produced mainly from petrochemicals, by-products of petroleum and natural gas refineries. (Refer to Appendix C by C. Weaver for a discussion of plastics and their use in the automobile.) As can be seen in Figure 61, the principal petrochemical monomers used by the plastics industry are ethylene, benzene, and propylene. The olefins, ethylene and propylene, have been produced principally from natural gas liquids (ethane, propane, and butane), because of natural gas domestic availability and stable, relatively low prices.

Ethylene enjoyed high yields of 70% of total NGL's. However, because of anticipated shortages of natural gas, there has been increased reliance on naphtha, a heavier petroleum-based feedstock in greater availability in the world, in the manufacture of the olefins to meet projected expansions of demand. Newer plants are being built to use this feedstock. Yields of ethylene from naphtha are considerably lower at 35%, while there is a greater amount of propylene produced as a by-product. Benzene, an aromatic, is generated primarily by oil refineries, though a small percentage (less than 10%) is derived from coal.



Source: Report to Congress on Petrochemicals, FEC, p. 38.

Figure 61. Schematic of Raw Materials for Principal Plastics/Resins

During the past 20 years, growth in the plastics industry has been spectacular. In 1973, growth was inhibited during the latter half of the year because of feedstock shortages. Potential shortages in 1974 and 1975 were not as great as they might have been because of the recession and resultant decrease in demand for plastics. One problem which the industry faces is inadequate capacity to meet its expected rate of growth. Another has been increased demand by other sectors in the economy for petrochemicals. For example, benzene has been diverted to other uses, such as raising the octane level of lead-free gasoline, and has faced increased demand overseas. The plastics industry has made plans for plant expansions through the latter part of this decade which should be able to meet anticipated demand, as can be seen in Table 09. However, inadequate capacity is still the major constraint upon industry growth.

The other major constraint on future plastics production is the availability of raw materials. Barring the discovery of new petroleum or natural gas fields or the development of alternative sources of energy, plastics production will be limited by the supply of natural gas and crude petroleum until there is a technological breakthrough in the recycling of plastics, development of elemental synthesis of plastics or alternative raw material feedstock. Research is under way on the possibility of converting foodstuffs, such as cornstarch or the castor bean, into raw materials for plastics. Castor oil is currently being used as a raw material for nylon and for other uses in plastics production. Research is also being conducted on process innovations for higher yields. Industry representatives conclude that new energy sources will not be developed in time to meet the expected demand of the plastics industry in the 1980's. What will occur will be an increased dependence upon Middle Eastern oil as heavy liquids (i.e., naphtha) become the major source for production of ethylene by the early 1980's. In the long run, what is critical for the plastics industry is the rate at which the energy crisis is solved.

TABLE 69

MONOMER MANUFACTURING CAPACITY AND CONSUMPTION BY PLASTICS
BASED ON INDUSTRY EXPANSION PLANS
(MILLION METRIC TONS)

Monomer	Present Capacity 1974	Projected Capacity 1980
US:		
Ethylene Capacity	12.0	19.0
Plastics Consumption of Ethylene	8.0	12.73
Polyethylene 45%		
PVC 12%		
Styrenics 10%		
Benzene Capacity	5.0	9.0
Plastics Consumption of Benzene	2.0	3.6
Styrene 40%		
Propylene Capacity	5.0	9.0
Plastics Consumption of Propylene	1.5	2.7
Acrylic, ABS, 30% SAN, Polycarbonate, Polypropylene		
Rest of World:		
Ethylene		16.0
Styrene		.25
Benzene		.8
Demand for Plastics Created by Renner Maximum Credible Plastic Car		1.3 (1980)-2.3 (1990)

Source: 1975:2000 Plastics the Next 25 Years, publication of Modern Plastics, pp. 4-6.

The principle that availability of resources depends upon existing technology and the price of extraction applies also to the fossil fuels, natural gas, and crude oil, which produce the feedstock for the production of plastic resins. However, unlike aluminum, iron ore, and other elements abundant in the earth's crust, the supply of fossil fuels economically recoverable in the earth is nowhere near as great. Another difference is that they are consumed as they are used, preventing the possibility of recycling. The judicious management of these resources is a must and points to the necessity of developing alternative sources of energy. The major use of energy is for normal home and industrial heating purposes. If a nonexhaustible or other alternative source of energy, such as solar energy, were developed, there would be enough fossil fuels for industrial applications such as plastics. One possible source that could be exploited in the meantime for heating purposes is the heat potential in waste plastic. The rate at which the energy problem is solved is critical. Whether or not world supplies of petroleum and natural gas are available in sufficient quantity to meet projected demand through the end of this century remains to be seen. In any case, they will be available at a considerably higher price.

TABLE G10

ASSESSMENT OF WORLD NATURAL GAS RECOVERABLE AT VARIOUS WELLHEAD PRICES[1] (TRILLION CUBIC FEET)

	Price Constant 1972 Dollars per 1,000 Cubic Feet			
	0.186[2]	0.34	0.44	0.55+
North America:				
United States	266	580	900	2,349
Other	40	480	950	1,750
Total	306	1,060	1,850	4,099
Rest of World:	850	5,530	8,570	11,500
World Total:	1,156	6,130	10,420	15,599

[1]There is insufficient information to determine the availability of potential resources at various prices. The value of domestic resources is based on a Bureau of Mines forecast of probable demand.

[2]1972 average price $0.186 per 1,000 cubic feet.

Source: Mineral Facts and Problems, US Bureau of Mines.

TABLE 611

- Assessment of estimated world crude oil recoverable at various prices
(Constant 1972 dollars per barrel and billion barrels)

	Average 1972 price 1/ (Dollars)	Proved reserves 2/ (Billion barrels)	100 percent increased price (Dollars)	Proved reserves 3/ (Billion barrels)
North America				
United States	3.39	36.3	6.78	38.1
Other	2.97	15.0	5.94	16.5
Total	—	51.3	—	56.4
South America	2.39	28.3	4.68	31.1
Europe	c/ 3.25	90.4	6.50	99.7
Africa	3.43	106.4	6.80	117.0
Asia	2.43	368.0	4.86	405.1
Oceania	2.60	2.3	5.20	2.5
World total	—	666.9	—	733.5

c/ Continental.
1/ U.S. price from Bureau of Mines. Others are posted prices from representative countries.
2/ From American Petroleum Institute and Oil and Gas Journal.
3/ Data to quantify reserve-price relationships are not available. For planning purposes it was assumed that a 100 percent increase in price would increase reserves by 10 percent.

Source: Mineral Facts and Problems, US Bureau of Mines.

G.3.2 Price

As was stated in the last section, availability of raw materials is a function of technology and the price of extraction. Based on projected economic demand and supply relationships, the prices for aluminum and iron, two of the most abundant materials in the earth, should remain at a relatively constant level through the foreseeable future. However, as was noted in the discussion of plastics, the availability of fossil fuels is limited. Substantially higher prices are to be expected as high world demand for them continues and reserves approach exhaustion. The availability and price of fossil fuels affects not only the production of plastics, but also the production of iron and steel and aluminum, of industries which use a substantial amount of energy in the process of production. The quadrupling of the price of crude oil in 1974 by OPEC, the Organization of Petroleum Exporting Countries, had an impact on the prices of iron and steel and aluminum as can be seen in Table G12.

1. Aluminum

Bauxite, alumina, and aluminum are not traded on commodity exchanges and only aluminum has a published price. Bauxite and alumina transactions are usually handled within integrated companies or are based on long-term contracts. Published aluminum metal prices in the United States have tended to be stable, as can be seen in Table G13. In 1963, it was 23¢ per pound. Between 1970 and 1973 it fluctuated between 25¢ and 29¢ per pound. The effective selling prices, however, fluctuate with discounts given from published prices during periods when refining capacity exceeds demand (for example, during 1970-71 the published price was 29¢ while sales prices were reported as low a 22¢ per pound). In 1973, prices remained constant, with world prices as much as 25% higher than

TABLE G12

COMPARISON OF PRICES BASED ON

WHOLESALE PRICE INDEX (1967=100)

	Crude Petroleum	Electric Power	Aluminum Ingot, Primary	Steel Mill Products	Plastic Materials and Resins
1967	100.0	100.0	100.0	100.0	100.0
1968	100.6	100.9	102.5	102.5	91.4
1969	105.2	101.8	108.9	107.4	90.4
1970	108.1	105.9	113.2	114.2	90.6
1971	113.2	111.6	116.2	123.0	88.9
1972	113.8	121.5	87.0	130.4	86.7
1973	126.0	129.1	101.5	134.1	92.1
1974	211.8	163.7	151.3	170.0	143.8
1974					
Jan	178.4	137.5	119.2	138.1	93.7
Feb	201.7	142.2	119.2	140.0	96.3
Mar	201.7	148.9	139.8	146.6	116.1
Apr	201.7	151.4	148.1	150.0	123.9
May	201.7	159.7	149.6	152.4	128.0
Jun	201.7	164.7	153.8	169.0	140.8
Jul	224.4	167.6	156.8	181.2	147.5
Aug	225.2	170.5	165.8	187.9	160.7
Sep	225.4	173.6	170.5	190.1	176.6
Oct	226.2	176.3	164.6	190.9	179.1
Nov	231.0	179.7	163.9	191.2	181.3
Dec	223.0	180.3	163.9	191.9	183.2
1975					
Jan'	223.1	183.3	159.9	195.9	183.0
Feb	226.6	186.5	158.9	195.6	182.2
Mar	230.2	191.1	158.9	195.6	182.1
Apr	232.2	194.6	157.0	196.3	182.1
May	234.2	192.9			
Jun	256.0	190.6			

Source: Wholesale Price Index, published by Bureau of Labor Statistics.

TABLE G13

TIME-PRICE RELATIONSHIP FOR ALUMINUM

AVERAGE ANNUAL PRICE, DOLLARS PER POUND

	Actual Price	Constant 1972 Dollars	
1953	.21	.35	
1954	.24	.36	
1955	.22	.35	
1956	.26	.40	
1957	.26	.39	
1958	.25	.37	
1959	.27	.39	
1960	.26	.37	
1961	.25	.36	
1962	.24	.33	
1963	.23	.31	
1964	.24	.32	
1965	.24	.32	
1966	.25	.32	
1967	.23	.29	
1968	.24	.29	
1969	.25	.28	
1970	.23	.25	
1971	.22	.23	
1972	.23	.23	
1973	.25	NA	
1974	.39	NA	
1985		.33	(estimated)
2000		.46	

NA = Not Available.

Source: Mineral Facts and Problems, US Bureau of Mines.

TABLE G14

ESTIMATED ENERGY REQUIREMENTS

TO MAKE 1 SHORT TON OF PRIMARY ALUMINUM

	Carribbean Bauxite	South American Bauxite
Bauxite, short ton	4.7-5.0	4.0-4.5
Energy (million BTU's)		
Mining and Drying (oil, gas, elec)	1-2	2-3
Shipping to US Ports (oil)	3-5	6-8
Alumina, short ton	1.92-1.93	1.92-1.93
Energy (million BTU's)		
Steam (coal, oil, gas)	20-26	10-15
Calcining Alumina (oil, gas)	7-10	7-10
Other (coal, oil, gas, elec)	3-4	3-5
Primary Metal	Type of Anode Replacement	
Energy (million BTU's)	Prebaked	Soderberg
Alumina Reduction (elec)	48-60	55-60
Electrodes		
Petroleum, Coke (700-750 lbs)	8-10	9-10
Pitch (270-310 lbs)	3-4	3-4
Anthracite Coal (45-70 lbs)	0.5-0.8	0.7-1
Anode Baking (prebaked only) [a]	3.5-10.2	3.3-5
Holding Furnace Operations (gas, oil)		
Summary Energy Total (million BTU's)		
Bauxite	4-11	4-11
Alumina	20-40	20-40
Primary Metal	60-85	70-80
Total Energy	84-136	94-131
Total Energy [a]	160-247	196-242

[a] If electricity for alumina reduction is thermally generated at 35% efficiency.

Source: Mineral Facts and Problems, US Bureau of Mines.

the US published price because of US price controls. On September 3, 1974, the published price reached 39¢ per pound in response primarily to the doubling of the effective cost of bauxite from $15 to $30 per ton to aluminum companies, initiated by Jamaica and followed by the other member nations of the I.B.A. (International Bauxite Association), by raising their taxes and royalties on bauxite to comparable levels. According to industry representatives, a doubling of the cost of bauxite to aluminum companies adds less than 10% to the cost of aluminum metal. Other factors contributing to the latest price rise were increasing costs of labor, capital, and energy. Energy, given present aluminum technology, will become a greater factor in aluminum prices as the cost for its use becomes more expensive. As can be seen in Table G14, the B.T.U. requirements (supplied mostly be electricity) to produce one short ton of primary aluminum metal are significant. In fact, in response to rising energy costs, aluminum companies have proposed to raise the price of aluminum metal again this year (1975), but they are waiting for government approval. Based on Bureau of Mines estimates, the current price of $ .39 per pound for aluminum metal is higher than the long-term price of $ .36 that would support the development of other US aluminum-bearing ores in the earth's crust and make the aluminum supply virtually unlimited. Research and development this year have been intensified in response to the higher prices.

2. Iron and Steel

As can be seen in Table G15, prices for pig iron and steel have tended to be stable. Recent price rises can be attributed to a worldwide boom in the industry, led by high European demand. However, rising costs for labor, scrap, ferroalloys and energy have had impacts. Price increases during 1973 and 1974 were not as great as they might have been because of Cost of Living Council controls, which delayed and limited proposed price increases.

TABLE G15

TIME-PRICE RELATIONSHIP FOR IRON AND STEEL

AVERAGE ANNUAL PRICE

	Pig iron (dollars per gross ton)	Steel F.O.B. (dollars per pound)
1950	47.85	3.867
1951	52.70	4.131
1952	53.82	4.237
1953	55.96	4.516
1954	56.59	4.712
1955	57.78	4.977
1956	61.15	5.358
1957	65.15	5.800
1958	66.45	6.060
1959	66.41	6.196
1960	66.39	6.196
1961	66.44	6.196
1962	66.00	6.196
1963	63.26	6.273
1964	63.11	6.360
1965	63.11	6.360
1966	63.11	6.399
1967	63.12	6.464
1968	63.15	6.599
1969	63.96	7.091
1970	69.83	7.650
1971	76.10	8.429
1972	79.69	8.999
1973	78.57	9.380
1974	122.00	11.200

Source: Iron Age, January Annual Statistical Issue, representing composite price.

3. Plastics

Prices for plastic materials and resins generally have been quite stable in recent years, reflecting a downward trend over time as can be seen in Table G16. However, in 1974, this trend was reversed and prices for plastic resins showed dramatic increases as can be seen in Table G17. Industry spokesmen claim that only 5-10% of the price of plastics, depending on type, are a function of the price of crude oil, which quadrupled in price in 1974 on the international market. However, these price increases reflect not only the increased costs of raw materials, but also increased costs for labor, transportation, money, and plant construction. Industry representatives expect price levels to remain high.

Dow Chemical, a major producer, has begun to take a pricing approach that assumes the cost of replacement as the basic factor in pricing decisions, as opposed to a sufficient return on capital investment. Seeing inadequate resin capacity as a major deterrent to growth, and considering the cost of capital and raw material, Dow planners insist that their profit margins have to be adequate to support future expansions in the resins and feedstocks in which the company has a position.[1] Union Carbide has identified four factors that will lead to higher pricing through the end of the decade. "The company projects a rise in the cost of domestic naphtha (which it sees also as the major future feed for ethylene and propylene) to imported nanhtha levels by 1977. By that time, says the company, domestic ethylene will have risen to a range of 14 to 16¢/lb., propylene will be at 10 to 12¢/lb. and benzene will be selling in a range of 90¢ to $1.15/gal."[2] Other factors mentioned were: plant construction cost, cost of capital, and a profitability rate assuring a 5 to 10% net return on investment to generate the capital internally necessary for growth. The cost of labor, distribution, and overhead will also play a role in pricing decisions.

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[1] Modern Plastics, "Now's the time to tell if Producers Have Learned their Lesson on Pricing," Jan. 1975, p. 10.

[2] Ibid.

TABLE G16

TIME-PRICE RELATIONSHIP FOR

PLASTICS & RESIN MATERIALS

	Price
1950	.30
1951	.35
1952	.36
1953	.35
1954	.27
1955	NA
1956	.33
1957	.33
1958	.31
1959	.32
1960	.31
1961	.29
1962	.26
1963	.27
1964	.24
1965	.25
1966	.24
1967	.22
1968	.20
1969	.20
1970	.19
1971	.19
1972	.19
1973	.20

N.A. Not Available

Source: Synthetic Organic Chemicals, US Tariff Commission.

6.3.3 Projection of Substitute Material Costs for Alternative Designs of the Automobile

The cost of energy is expected to have an impact on the costs of the substitute materials for the automobile in the near future. A comparison of their B.T.U. requirements in Table 618 indicates that primary aluminum uses three times more B.T.U.'s than the next highest user, stainless steel. However, secondary aluminum was the lowest energy user. The reason for the discrepancy in requirements of primary and secondary aluminum is that the largest energy requirements are for the separation of primary aluminum from oxides. The implications for the secondary aluminum industry could be significant. Another interesting fact indicated by this table is that plastics, though directly requiring fossil fuels as a raw material, use only one quarter of the energy required for primary aluminum.

To measure just how much impact the increased cost of energy will have on the price of materials for automobiles, an estimate was made of the percentage of energy and other raw material costs for each material based on data in the Census of Manufactures. It was found that a significant portion of primary aluminum B.T.U. requirements are met by electricity, for which fossil fuels are only a part of its costs. Based on the Federal Power Commission's report, Statistics of Privately Owned Electric Utilities in the United States, only 20% of costs of electric utilities were fossil fuels. The 20% factor was used to estimate the fuel cost of electricity. Bauxite, alumina, and secondary aluminum fuel costs were estimated based on their respective B.T.U. requirements. Plastics posed a special problem because of their complexity and reliance upon fossil fuel as a raw material. To estimate the total costs of fossil fuel and other raw materials, the costs determined in the IR&T study, The Economic Impact of Water Pollution Control Costs Upon the Chemical Processing Industries, were used. The results of this analysis are listed in table 619. It was found that the percentage of

TABLE G18
ENERGY REQUIREMENTS FOR
AUTOMOTIVE MATERIALS

	Energy BTU/#)
Plain Carbon Steel	21,000
Stainless Steel	34,000
Alloy Steel	22,300
Galvanized Steel	21,500
Aluminized Steel	21,500
Cast Iron	10,300
Nodular Iron	14,050
Malleable Iron	15,500
Aluminum, rolled/drawn (primary)	110,000
Aluminum, cast (secondary)	10,000
Plastics (composite)	25,000

Source: Samples, Dorian K., "Energy Use in the Automobile", Table I, p.33.

TABLE 619

COSTS OF MANUFACTURE AS PERCENTAGE OF TOTAL COST

	Raw Materials	Energy	Value Added
Ferrous Metals	47.5	9.6	42.5
Aluminum			
—Primary	48.6	9.6	42.6
—Secondary	77.0	4.1	19.9
Plastics			
—HDPE	2.28	26.29	71.43
—LDPE	2.28	26.29	71.43
—Polypropylene	2.15	10.98	86.87
—PVC	17.26	15.57	67.15
—Polyurethane	15.96	.28	83.86
—ABF & SAN Resins	39.69	6.77	60.54

Source: 1972 Census of Manufactures and The Economic Impact of Water Pollution Control Costs from the Chemical Processing Industries, 1987.

energy costs for such plastic types as the polyethylenes are greatest, while the percentage of costs for primary aluminum and iron and steel are comparable at 10%.

To measure the potential impact of an increase in energy cost upon substitute materials in the alternative designs of the automobile and determine which design would be least affected, a comparison was made of the required materials for each design at projected costs. Three scenarios were developed: (A) a doubling of energy cost, (B) a tripling, and (C) a quadrupling of energy cost. As a base case, the cost of materials in 1973 before the cartel actions by OPEC and I.B.A. were used. The scenarios were chosen to show the relative impact of increases in the cost of energy as opposed to being actual projections of prices. This analysis makes the assumption that the prices for all forms of energy will rise comparably.

Table G20 presents the results of this analysis. It shows that the maximum credible plastics car will have a slight competitive advantage in cost in spite of energy cost increases. The five plastic types listed include over 70% of all plastics used in the automobile in 1973. They were chosen for this analysis because they were the likely candidates for increased use in the future, particularly high-density polyethylene, polypropylene, and polyvinyl chloride. All have energy costs in excess of 10%. One reason plastics were able to maintain their competitive advantage over aluminum in the automobile was their present low cost vis-à-vis the other materials and their lower weight requirements in the alternative designs. The impact of energy cost increases was not sufficient to make a difference.

The analysis did not take into account the impact of the I.B.A. cartel action on the price of aluminum. If it did so, aluminum would have been at a further competitive disadvantage because the price selected for the base year was significantly lower than the price resulting from the I.B.A. action. The Bureau of Mines has estimated that it takes up to 5 years for the aluminum industry to respond to the

price level now in effect and several additional years to develop the capacity to produce enough aluminum from domestic sources to be self-sufficient. The industry will be vulnerable to further price increases imposed by the I.B.K. during the period necessary to develop the capacity to produce aluminum from domestic clays.

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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6.4 Conclusion

A comparison of the three designs at projected levels of cost as a function of energy favors the maximum credible plastic car. However, the major economic constraint upon the full potential use of plastics in the automobile may be the availability of petrochemical raw materials. Supplies of aluminum and iron are more plentiful than fossil fuels. Because the energy requirements for these materials are for their separation, substantial savings could be made if energy-efficient technologies were developed, thus improving their competitive position.

6.5 REFERENCES

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14. US Department of the Interior, Critical Materials; Commodity Action Analysis, Office of Minerals Policy Development, March, 1975.

G.6 Annex to Appendix G.

A necessary step to analyze the future demand for these materials as projected by Roy Renner in Appendix A was to develop a production-weighted composite car, in contrast to the sales-weighted car. The reason for this was that the sales-weighted percentages include imports, which consist mainly of smaller, lighter vehicles. Using the categories defined by R. Roig, and his methodology developed in Appendix B, it was projected that in 1975, 57% of the cars produced would be Class "A" full-size, 30% Class "B" compact, and 14% Class "C." Tables G-22 through G-29 give the detailed breakdowns of the composite automobile under the alternative designs. The 1975 production-weighted composite is about 300 pounds heavier than the sales-weighted model with future models about 100-150 pounds heavier.

TABLE G-22

PROJECTED PRODUCTION SHARES

	1979	1980	1990
Car A	57	38	38
Car B	30	37	37
Car C	14	25	25

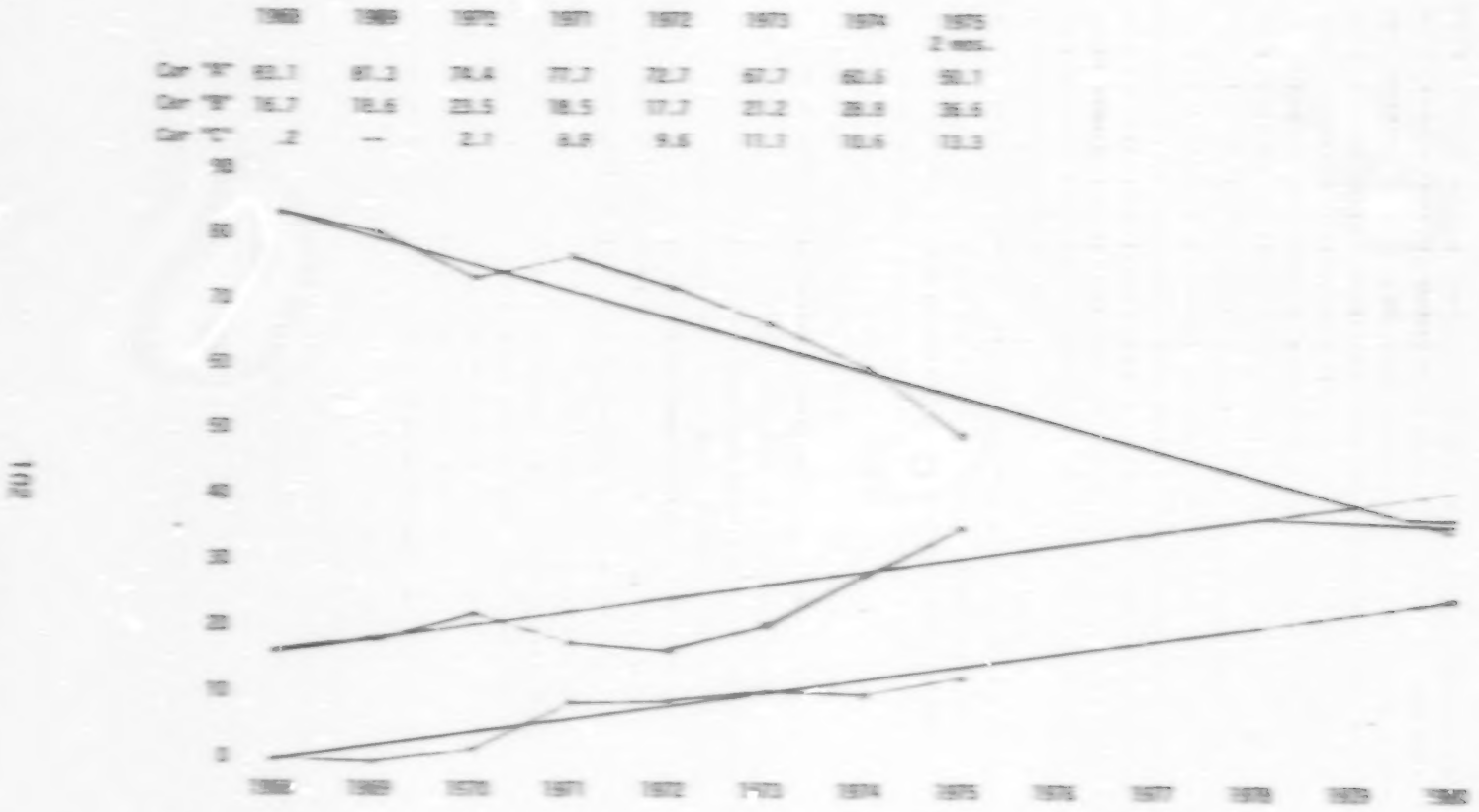

Figure 62. MDMS Data of 3 U.S. Market

TABLE G23

BASELINE MATERIALS COMPOSITION: TYPICAL 1975 MODEL AUTOMOBILES PRODUCED IN THE UNITED STATES

	Automobile "A" Full-Size		Automobile "B" Compact		Automobile "C" Sub-Compact		Composite Automobile (Production Weighted)(a)	
	Wt., lb	Wt.%	Wt., lb	Wt.%	Wt., lb	Wt.%	Wt., lb	Wt.%
Low Carbon Steel	2400	55.3	1659	55.3	1186	54.4	2032	55.2
Alloy Steel (b)	260	6.0	180	6.0	131	6.0	226	6.0
Total Steel	2660	61.3	1839	61.3	1317	60.4	2258	61.2
Cast Iron (c)	716	16.5	495	16.5	316	14.5	601	16.3
Aluminum	117	2.7	81	2.7	87	4.0	103	2.8
Copper, Brass	40	0.9	30	1.0	25	1.1	36	1.0
Zinc	35	0.8	24	0.8	17	0.8	29	0.8
Lead	25	0.6	22	0.7	20	0.9	24	0.7
Other Metal (d)	10	0.2	8	0.3	10	0.5	9	0.2
Rubber	195	4.5	135	4.5	100	5.5	160	4.6
Glass	100	2.3	75	2.5	60	2.8	87	2.4
Plastic	150	3.5	105	3.5	76	3.5	129	3.5
Other Non-Metal	292	6.7	196	6.2	132	6.0	240	6.5
Totals (e)	4340	100.0	3000	100.0	2160	100.0	3679	100.0

Notes

(a) Assuming 67% Class "A", 30% Class "B", 14% Class "C"

(b) Including stainless steels

(c) Including malleable iron

(d) Including tin, magnesium. Alloying materials such as manganese, nickel, chromium, and tungsten are included in the steel weights.

(e) Total dry weights without fuel or fluids

TABLE G24

PROJECTED MATERIALS COMPOSITION: 1980 MODEL AUTOMOBILES
BASIS: MOST PROBABLE MATERIALS CONTENT

	Automobile "A" Full-Size		Automobile "B" Compact		Automobile "C" Sub-Compact		Composite Automobile (Production Weighted)(a)	
	Wt.-lb	Wt.%	Wt.-lb	Wt.%	Wt.-lb	Wt.%	Wt.-lb	Wt.%
Low Carbon Steel	1971	51.8	1332	49.8	1008	49.7	1498	50.5
Alloy Steel (b)	251	6.5	174	6.5	123	6.1	191	6.4
Total Steel	2220	57.7	1506	56.3	1134	56.0	1687	56.9
Cast Iron (c)	523	13.5	383	14.3	259	12.8	406	13.7
Aluminum	229	5.9	166	6.2	146	7.2	185	6.2
Copper, Brass	35	0.9	26	1.0	22	1.1	29	1.0
Zinc	17	0.4	12	0.4	9	0.4	12	0.4
Lead	25	0.6	22	0.8	20	1.0	23	0.8
Other Metal (d)	20	0.5	20	0.7	20	1.0	20	0.7
Rubber	189	4.9	131	4.9	118	5.9	150	5.0
Glass	95	2.5	71	2.7	57	2.8	76	2.6
Plastic	261	6.8	182	6.8	124	6.3	198	6.7
Other Non-Metal	242	6.3	156	5.8	112	5.5	170	6.0
Totals (e)	3884	100.0	2675	99.9	2025	99.9	2964	100.0

Notes

(a) Assuming 38% Class "A", 37% Class "B", 25% Class "C"

(b) Including stainless steels

(c) Including malleable iron

(d) Including tin, magnesium. Alloying materials such as manganese, nickel, chromium, and tungsten are included in the steel weights.

(e) Total dry weights without fuel or fluids

TABLE G25

PROJECTED MATERIALS COMPOSITION: 1980 MODEL AUTOMOBILES

BASIS: MAXIMUM CREDIBLE ALUMINUM CONTENT

	Automobile "A" Full-Size		Automobile "B" Compact		Automobile "C" Sub-Compact		Composite Automobile (Production weighted)[c]	
	wt.,lb	wt.%	wt.,lb	wt.%	wt.,lb	wt.%	wt.,lb	wt.%
Low Carbon Steel	1774	49.8	1184	47.7	909	47.9	1346	48.7
Alloy Steel [b]	247	6.8	171	6.9	126	6.6	183	6.6
Total Steel	2039	56.4	1355	54.6	1035	54.4	1535	55.5
Cast Iron [c]	307	8.5	224	9.0	163	8.0	238	8.6
Aluminum	419	11.6	312	12.6	244	12.9	335	12.1
Copper, Brass	25	.7	18	.7	16	.8	21	.8
Zinc	17	.5	12	.5	9	.5	12	.4
Lead	25	.7	22	.9	20	1.1	23	.8
Other Metal [d]	20	.6	20	.8	20	1.1	20	.7
Rubber	100	5.2	109	5.2	117	6.2	109	5.4
Glass	95	2.6	71	2.9	57	3.0	78	2.8
Plastic	234	6.5	161	6.5	114	6.0	170	6.4
Other Non-Metal	242	6.7	166	6.3	112	6.0	170	6.4
Totals [e]	3611	100.0	2480	100.0	1897	100.1	2764	100.0

Notes

(a) Assuming 38% Class "A", 37% Class "B", 25% Class "C"

(b) Including stainless steels

(c) Including malleable iron

(d) Including tin, magnesium. Alloying materials such as manganese, nickel, chromium, and tungsten are included in the steel weights.

(e) Total dry weights without fuel or fluids

TABLE G26

PROJECTED MATERIALS COMPOSITION: 1980 MODEL AUTOMOBILES

BASIS: MAXIMUM CREDIBLE PLASTICS CONTENT

	Automobile "A" Full-Size		Automobile "B" Compact		Automobile "C" Sub-Compact		Composite Automobile (Production Weighted)(a)	
	wt.,lb	wt.%	wt.,lb	wt.%	wt.,lb	wt.%	wt.,lb	wt.%
Low Carbon Steel	1640	48.9	1228	47.1	946	37.6	1303	46.1
Alloy Steel (b)	230	6.6	173	6.6	127	6.4	181	6.6
Total Steel	2099	55.5	1401	53.7	1071	54.0	1504	54.7
Cast Iron (c)	520	13.8	380	14.6	267	13.0	403	13.9
Aluminum	190	5.2	140	5.4	108	6.5	158	5.5
Copper, Brass	38	.9	28	1.0	22	1.1	29	1.0
Zinc	17	.5	12	0.5	9	0.5	12	0.4
Lead	25	.7	22	0.8	20	1.0	23	0.8
Other Metal (d)	20	.5	20	0.8	20	1.0	20	0.7
Rubber	188	5.0	130	5.0	118	6.0	149	5.1
Glass	95	2.5	71	2.7	57	2.9	76	2.6
Plastic	340	9.0	247	9.5	168	8.5	262	9.1
Other Non-Metal	242	6.4	156	6.0	112	5.7	178	6.2
Totals (e)	3777	100.0	2605	100.0	1982	100.2	2894	100.0

Notes

(a) Assuming 38% Class "A", 37% Class "B", 25% Class "C"

(b) Including stainless steels

(c) Including malleable iron

(d) Including tin, magnesium. Alloying materials such as manganese, nickel, chromium, and tungsten are included in the steel weights.

(e) Total dry weights without fuel or fluids

TABLE 627

PROJECTED MATERIALS COMPOSITION: 1990 MODEL AUTOMOBILES

BASIS: MOST PROBABLE MATERIALS CONTENT

	Automobile "A" Full-Size		Automobile "B" Compact		Automobile "C" Sub-Compact		Composite Automobile (Production Weighted)[a]	
	Wt., lb	Wt.%	Wt., lb	Wt.%	Wt., lb	Wt.%	Wt., lb	Wt.%
Low Carbon Steel	1649	47.5	1074	46	837	46.3	1233	46.4
Alloy Steel [b]	276	8.0	191	8	141	7.8	212	8.0
Total Steel	1925	55.5	1266	53	978	54.1	1445	54.4
Cast Iron [c]	290	8.4	200	8.4	119	6.6	214	8.1
Aluminum	389	11.2	289	12.1	228	12.6	312	11.7
Copper, Brass	19	0.5	13	.5	12	.7	16	0.6
Zinc	10	0.3	6	.3	6	.3	8	0.3
Lead	20	0.6	16	.6	17	.9	19	0.7
Other Metal [d]	35	1.0	35	1.5	35	1.9	35	1.3
Rubber	158	4.6	127	5.3	101	5.6	132	5.0
Glass	90	2.6	68	2.8	54	3.0	73	2.7
Plastic	316	9.1	228	9.5	166	9.2	246	9.2
Other Non-Metal	218	6.3	140	5.9	101	5.6	160	6.0
Totals [e]	3470	100.0	2391	100.1	1807	99.8	2656	100.0

Notes

(a) Assuming 38% Class "A", 37% Class "B", 25% Class "C"

(b) Including stainless steels

(c) Including malleable iron

(d) Including tin, magnesium. Alloying materials such as manganese, nickel, chromium, and tungsten are included in the steel weights.

(e) Total dry weights without fuel or fluids

TABLE G2B

PROJECTED MATERIALS COMPOSITION: 1990 MODEL AUTOMOBILES

BASIS: MAXIMUM CREDIBLE ALUMINUM CONTENT

	Automobile "A" Full-Size		Automobile "B" Compact		Automobile "C" Sub-Compact		Composite Automobile (Production Weighted)[a]	
	Wt.,lb	Wt.%	Wt.,lb	Wt.%	Wt.,lb	Wt.%	Wt.,lb	Wt.%
Low Carbon Steel	1198	38.4	760	35.5	594	36.7	884	37.1
Alloy Steel [b]	272	8.7	188	8.8	139	8.6	204	8.7
Total Steel	1470	47.1	948	44.3	733	45.3	1092	45.9
Cast Iron [c]	136	4.3	87	4.1	63	3.8	94	3.9
Aluminum	720	23.1	530	24.8	398	24.6	570	24.0
Copper, Brass	19	0.6	13	0.6	12	0.7	15	0.6
Zinc	10	0.3	8	0.4	6	0.4	8	0.3
Lead	20	0.6	16	0.8	17	1.1	19	0.8
Other Metal [d]	35	1.1	35	1.6	35	2.2	35	1.5
Rubber	158	5.1	127	5.9	101	6.2	132	5.6
Glass	90	2.9	68	3.2	54	3.3	72	3.0
Plastic	242	7.8	167	7.8	118	7.3	184	7.7
Other Non-Metal	218	7.0	140	6.5	101	6.2	160	6.7
Totals [e]	3117	99.9	2141	100.0	1618	99.9	2381	100.1

Notes

(a) Assuming 30% Class "A", 37% Class "B", 25% Class "C"

(b) Including stainless steels

(c) Including malleable iron

(d) Including tin, magnesium. Alloying materials such as manganese, nickel, chromium, and tungsten are included in the steel weights.

(e) Total dry weights without fuel or fluids

TABLE 629

PROJECTED MATERIALS COMPOSITION: 1990 MODEL AUTOMOBILE

	Automobile "A" Full-Size		Automobile "B" Compact		Automobile "C" Sub-Compact		Composite Automobile (Production Weights)(a)	
	Wt.,lb	Wt.%	Wt.,lb	Wt.%	Wt.,lb	Wt.%	Wt.,lb	Wt.%
Low Carbon Steel	1319	40.5	825	37.3	675	40.0	976	39.4
Alloy Steel (b)	275	8.4	173	7.8	127	7.5	200	8.1
Total Steel	1594	48.9	998	45.1	802	47.5	1176	47.5
Cast Iron (c)	290	8.9	200	9.0	119	7.1	214	8.6
Aluminum	296	9.1	214	9.7	178	10.6	236	9.5
Copper, Brass	19	0.6	13	0.6	12	0.7	15	0.6
Zinc	10	0.3	8	0.4	6	0.4	8	0.3
Lead	20	0.6	18	0.8	17	1.0	19	0.8
Other Metal (d)	35	1.1	35	1.6	35	2.1	35	1.4
Rubber	150	4.6	127	5.7	101	6.0	132	5.3
Glass	90	2.8	68	3.1	54	3.2	73	2.9
Plastic	530	16.3	392	17.7	282	15.5	412	16.6
Other Non-Metal	210	6.7	140	6.3	101	6.0	160	6.5
Totals (e)	3260	100.1	2213	100.0	1687	100.1	2480	100.0

Notes

(a) Assuming 30% Class "A", 37% Class "B", 25% Class "C"

(b) Including stainless steels

(c) Including malleable iron

(d) Including tin, magnesium. Alloying materials such as manganese, nickel, chromium, and tungsten are included in the steel weights.

(e) Total dry weights without fuel or fluids